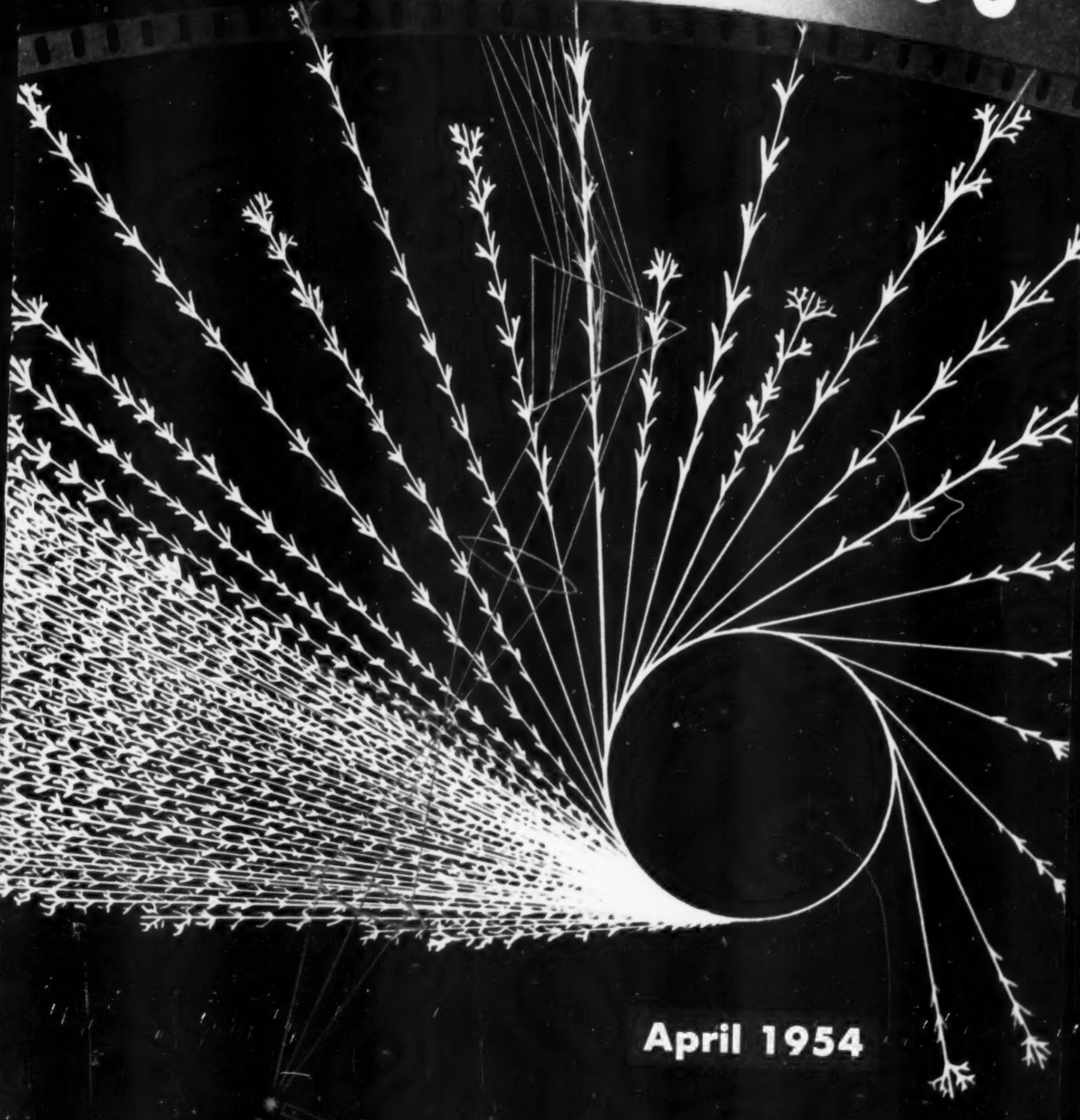
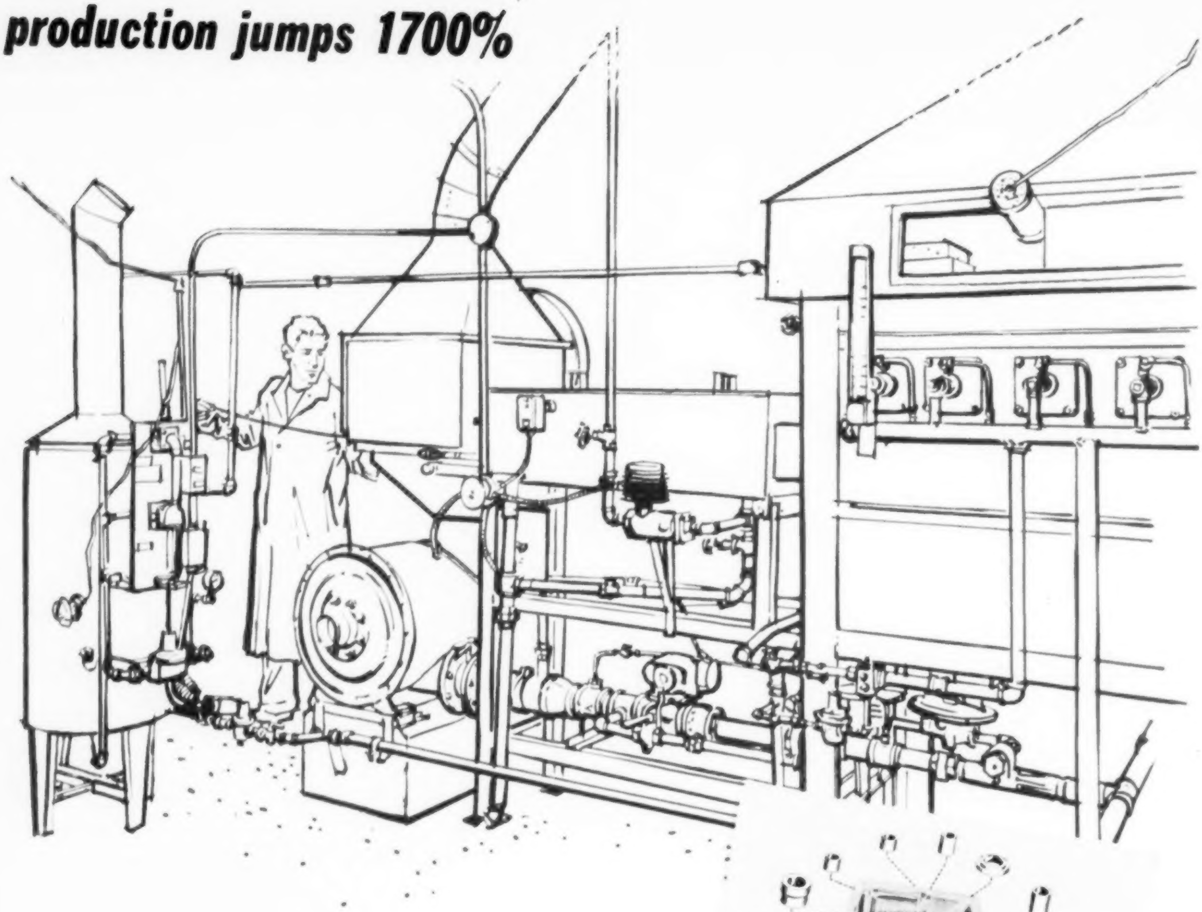
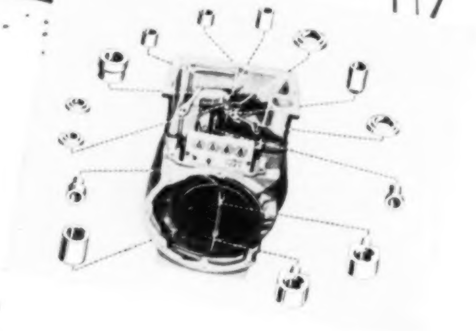
METAL PROGRESS



April 1954

production jumps 1700%





in 'powder room' for metal

When the American Meter Company started sintering precision parts for their meters, their production curve shot up like a scared rocket. For example, they formerly machined one of the bushings, with a production rate of 230 pieces per hour. The same part, of sintered bronze powder, is now turned out at a rate of 4,000 per hour! That's an increase of 1700%!

Meter buyers benefit from the changeover, too. Sintered parts improve meter operation: self-lubricating, they reduce friction loss that upsets accuracy, eliminate the necessity of continual maintenance.

Heart of the sintering process at American Meter is a Surface Combustion gas-fired muffle furnace with cooling chamber. Sintering of the metal powder (90% copper, 10% tin) is done at 1550°F. A 'Surface' automatic MAX generator provides a furnace atmosphere which protects the parts from deterioration. This equipment is also used to anneal steel and brass parts when production time is available. Surface Combustion will be glad to help you examine the possibilities of powder metallurgy. Write for Literature Group H53-9.

SURFACE COMBUSTION CORPORATION • TOLEDO 1, OHIO

ALSO MAKERS OF

Kathabar HUMIDITY CONDITIONING ***Janitrol*** AUTOMATIC SPACE HEATING

Metal Progress . . . . . . April, 1954 Vol. 65, No. 4

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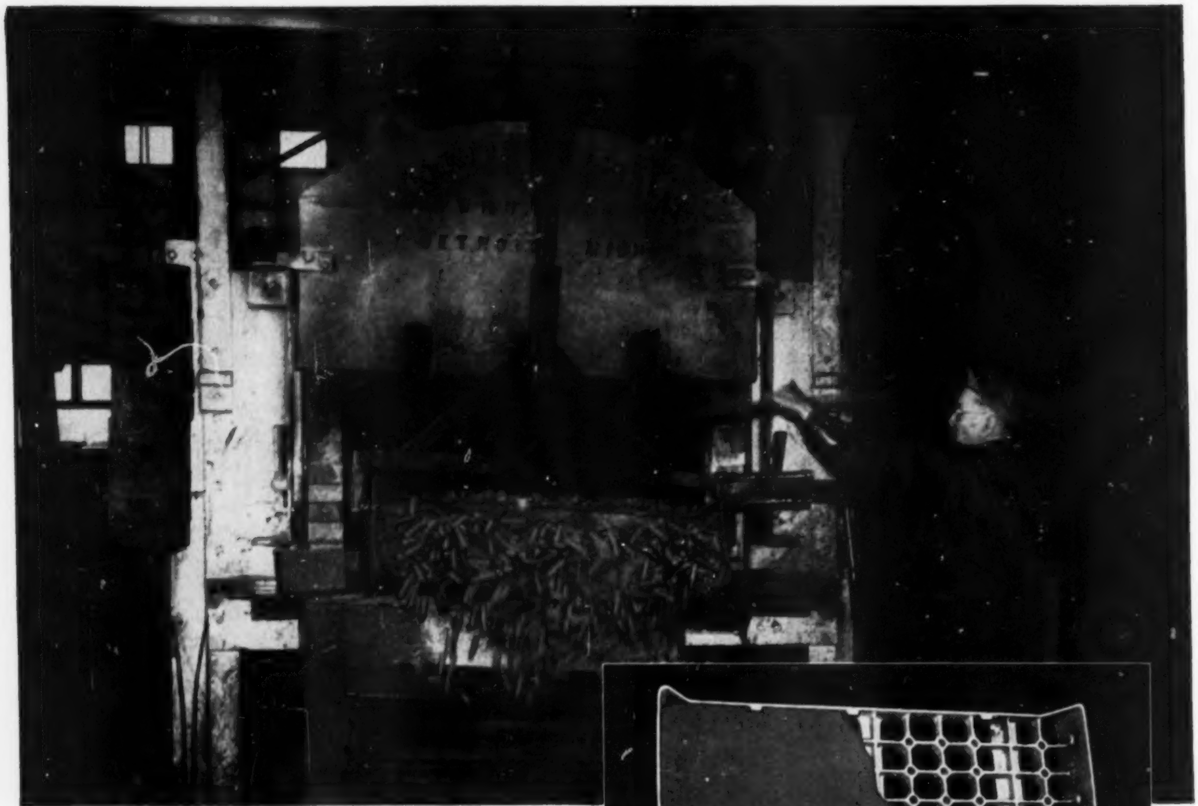
Cover by Donald C. Lorman



Cutaway section of Thermalloy plate insert shows integral grid design of Thermalloy tray used in this annealing furnace

THERMALLOY*

FURNACE TRAYS . . . *IN SERVICE OVER* 28 *MONTHS!*

At the Dostal Foundry & Machine Co. in Pontiac, Michigan, two 30′ annealing furnaces (pusher type) are used for stress relieving gray iron castings. During the 4 to 4½-hour process . . . with temperature ranging to 1640° F. . . . an average work load of 210 lbs. is carried on each heat-treat tray.

Previously used trays became cracked and twisted in service. Sometimes the work load was spilled to the furnace bed when the tray twisted out of shape . . . forcing a costly furnace shutdown.

Electro-Alloys recommended one-piece Thermalloy trays with integral grids to give maximum strength with a favorable alloy-work ratio. An alloy-plate insert was designed to keep work from falling to furnace bed. *28 months later,* these Thermalloy castings are still in service . . . and show little wear.

Thermalloy is a group of tough, heat-resistant alloys specifically developed to take heavy loads and rough usage . . . to resist corrosive gases and retain strength (up to 2100° F.). Electro-Alloys produces such types of Thermalloy castings as you may require . . . whether they be trays, pots, baskets, fixtures, rollers or radiant tube assemblies. Call your nearest Electro-Alloys representative for full information or write Electro-Alloys Division, 5002 Taylor Street, Elyria, Ohio, for the new Thermalloy Tray and Fixture Bulletin T-227.

*Reg. U. S. Pat. Off.

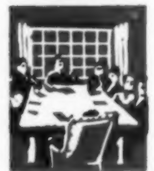
AMERICAN Brake Shoe COMPANY

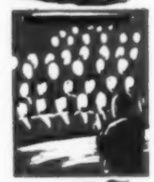
ELECTRO-ALLOYS DIVISION

ELYRIA, OHIO

As I was saying...

I HAVE JUST returned from visiting the chapters on the west coast and to state it mildly I am more than pleased to report the energetic and healthy condition of your western brothers. For a group of chapters interested in promoting and sponsoring successful educational courses it would be difficult to equal their accomplishments. The meeting of the chairmen and vice-chairmen of the chapters in the North West was the first of a series of similar regional meetings to be held in August, when plans and preparations for a vigorous chapter year will be inaugurated.





I had no more than returned from the balmy and sunshiny West when the Old Weather Man visited Cleveland with a 15-inch layer of snow. I was most vigorously accused of having brought this calamitous weather with me from the West and I admitted to it readily, informing all inquirers that the West didn't care for any such unusual weather.

Fortunately, I left that evening for Boston to complete preparations for the Mid-Winter Meeting and for a regular meeting of the Board of Trustees and a meeting of the Foundation for Education and Research.

The Mid-Winter Meeting was quite successful although the registration of approximately 400 was slightly less than the registration at Pittsburgh two years ago. The beryllium conference had four sessions of 18 papers dealing with the production, fabrication, properties and uses of beryllium. The session proved to be of major interest and attracted standing-room-only attendance. The material presented at this conference was new and enlightening and the reports and papers were the result of declassified material selected from the research work completed under the auspices of the Atomic Energy Commission.

The program at the Boston meeting consisted in the presentation of 16 papers dealing with physical metallurgy, hardenability, mechanical operations and stainless steel. All of the papers were preprinted and will be included in the present volume of *Transactions* (1680 pages) which should be in your hands by the time this issue of *Metal Progress* comes to your desk.

Altogether the Mid-Winter Meeting was a very successful operation. The Mid-Winter Meeting (California Chamber of Commerce, please excuse!!) for 1955 will be held in Los Angeles, March 21-25, simultaneously with the Western Metal Congress and Exposition.

The Foundation has authorized the granting of scholarships ($400) to the same 41 educational institutions giving degrees in metallurgy (35 in the U.S.A. and 6 in Canada) that received the scholarships last year. The Foundation decided to investigate additional institutions that might qualify for scholarships for the 1954-55 school year. The individual to receive these $400 scholarships is selected by the metallurgical department—preferably a sophomore entering upon a career in metallurgy.

At the meeting of the Board of Trustees a communication was read from Kenneth Headlam-Morley, secretary of the British Iron & Steel Institute and Honorary General Secretary of the European Committee for the Joint Metallurgical Societies Meeting, giving additional plans for the Congress, June 1 to 18, 1955. It was pleasing to note the progress being made by the representatives of the societies in the United Kingdom, France, Germany and Sweden who have the over-riding responsibility for the program.

Details are being forwarded to the members who have signified their interest in receiving promptly further information as it is completed. If your name is not on that list and you are interested, be sure to let headquarters know that you want to know.

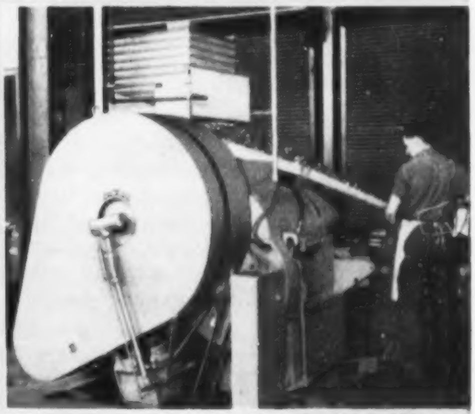
Cordially yours,

Bill

W. H. Eisenman, *Secretary*
American Society for Metals

Relies Entirely on NATIONAL for Modern Precision Forgings!

This 2500-ton Maxipres (one of 18) now in production in the modern forge shop of the Bingham-Herbrand Corp.



Six Reducerolls at Bingham-Herbrand quickly preform jet aircraft engine blade and bucket blanks for finish forging in Maxipresses.

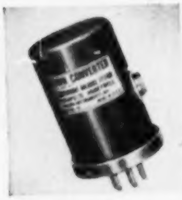
NATIONAL
MACHINERY COMPANY
TIFFIN, OHIO—SINCE 1874

DESIGNERS AND BUILDERS OF MODERN FORGING MACHINES • MAXIPRESSES • REDUCEROLLS • COLD HEADERS • BOLTMAKERS • NUT FORMERS • TAPPERS • NAILMAKERS

Hartford | Detroit | Chicago

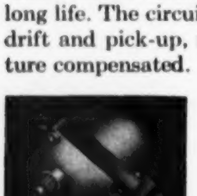
The "inside" story of *ElectroniK* instruments

Maybe you've never seen what's inside the case of an *ElectroniK* instrument. And even if you have, you might not realize how each component has been painstakingly refined to contribute its share to the overall performance and dependability of the instrument. Three of these components in particular—the converter, "Continuous Balance" amplifier and the balancing motor—are key members of the *ElectroniK* team with which you should get acquainted.



The Converter
is what transforms tiny direct-current signals from the thermocouple or other sensing element into an alternating voltage that the amplifier can conveniently handle. In principle, it is somewhat like the vibrator in your automobile radio. But because it deals with such small bits of electrical energy, it has been designed of carefully selected materials which prevent the introduction of misleading signals into the measuring system. It is hermetically sealed against the effects of dust, humidity and atmospheric pressure change, and is shielded against stray electrical and magnetic fields.

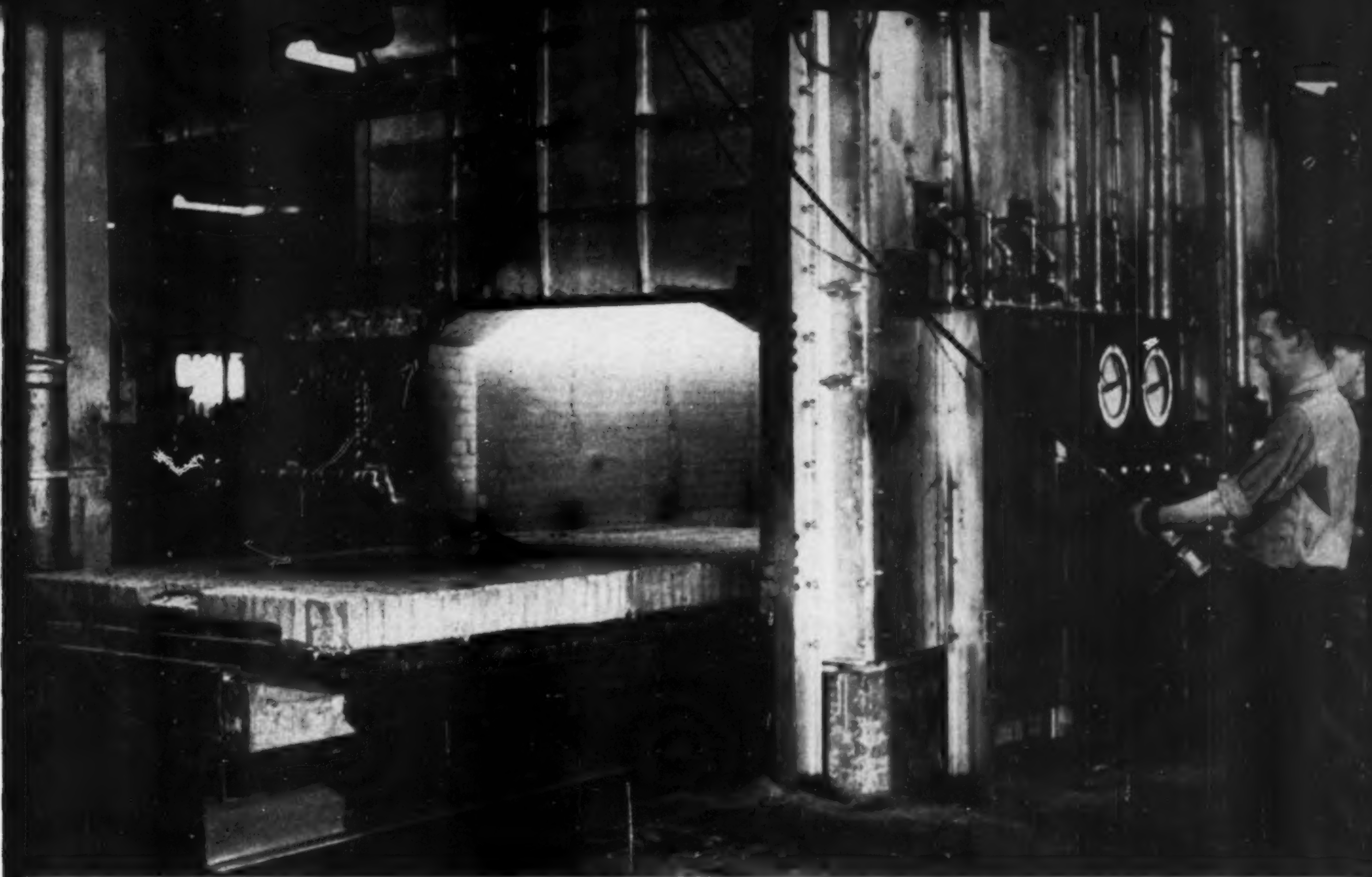
The "Continuous Balance Amplifier"
boosts the incoming signals by millions of times . . . makes them strong enough to operate the balancing motor. Although it looks like part of a radio chassis, few communications circuits could equal it for quality. It uses standard, easily obtained parts, which are operated far below their normal ratings to insure exceptionally long life. The circuit has great stability against drift and pick-up, and is thoroughly temperature compensated.

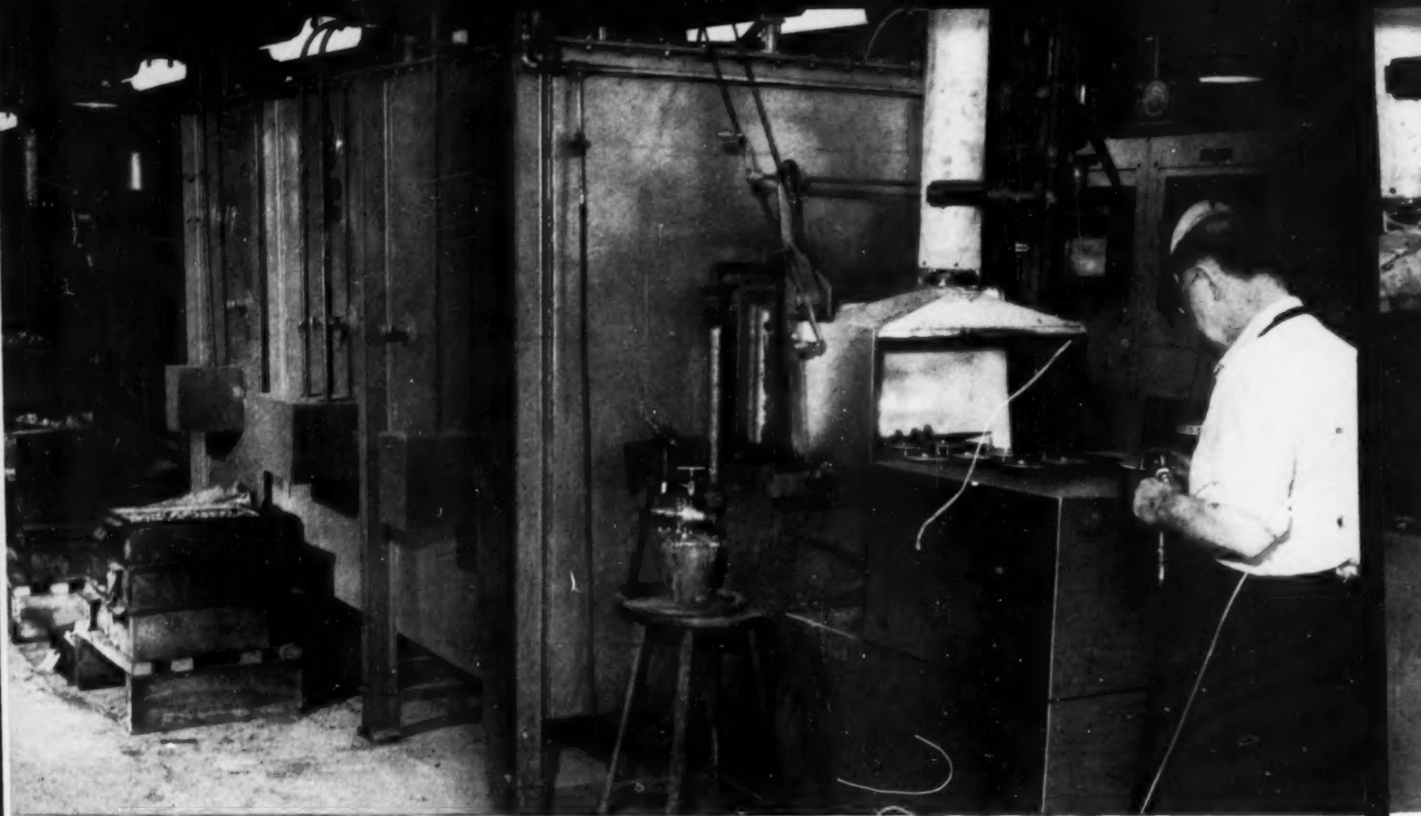


The Balancing Motor
does the work of moving the pointer, recording pen and any control devices that may be incorporated in the instrument. It packs plenty of power into a small space . . . gives ample torque to give fast, accurate positioning whenever the amplifier calls on it. Totally enclosed, the motor is impervious to dust, dirt and changes in mounting position.

Heat-treating output boosted at Yale & Towne . . . with *ElectroniK*

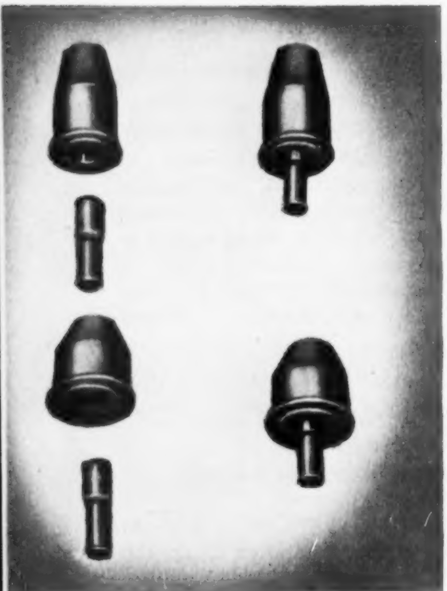
Listed in Catalog 1531 are the varied types of ***ElectroniK*** *Controllers . . . including electric and pneumatic systems affording a broad selection of control action.*



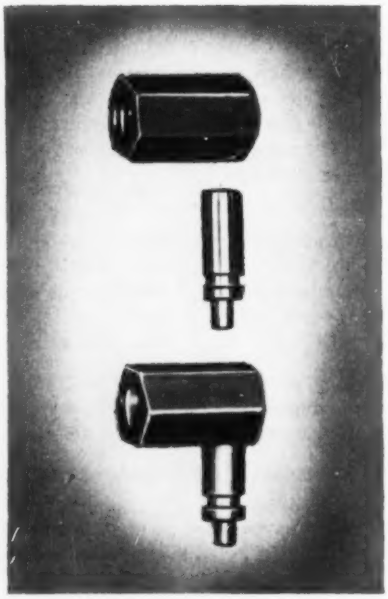


LOADING PARTS READY FOR BRAZING—Over 1350 assemblies per hour can be brazed by one man with this G-E mesh-belt furnace. Stewart Warner finds that maintenance costs on this furnace are even lower than estimated at the time of purchase.

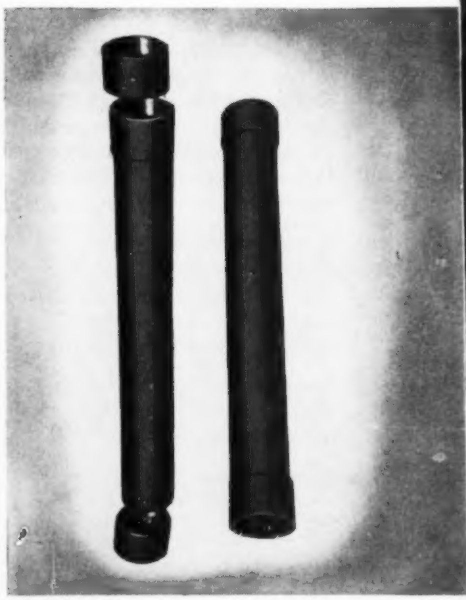
Stewart Warner Cuts Rejects up to 90%



NO HAND MACHINING—Now the ferrule bodies are screw-machine parts and the extensions are made on a punch press.



NO FORGING NEEDED—Now the components of this elbow (top) are made by screw machines and furnace brazed.



NO WELDING NEEDED—Production has been speeded by brazing rather than welding this cylinder assembly.

ONE OPERATOR BRAZES MANY PARTS—Copper brazing paste is applied as operator places assemblies on mesh-belt.

SMOOTH FILLETS—Brazed assemblies drop into tote box from G-E furnace clean and bright with smooth fillets at joints.

by Brazing in General Electric Furnace

Boosts Production and Lowers Costs By Eliminating Expensive Operations

Assembly rejects of metal ferrules cut 90%, material costs reduced, by brazing with a General Electric mesh-belt furnace, reports a large Chicago manufacturer of lubrication-system and automotive parts.

Says Henry Orth, General Foreman and Metallurgist of the Stewart Warner Corporation: "By brazing assemblies in a G-E furnace instead of welding them or machining the complete part from a single piece of stock, production per man hour has been boosted considerably. We've also been able to simplify the design of many parts. The over-all result: substantial savings in labor, handling, and material."

G-E FURNACE ELIMINATES 3 OPERATIONS

Machining—With furnace brazing, parts that formerly had to be machined in one piece can now be broken down into simple components for quick production at low cost on screw machines or punch presses.

Forging and Welding—Parts formerly welded, or forged and welded, are now electric-furnace brazed with less labor. One unskilled operator can braze several times the quantity that could be welded by one man. After brazing, the parts are clean and bright with smooth joints. No machining is required.

G-E APPLICATION ASSISTANCE

Stewart Warner's experience is another example of the benefits of modern metal processing with electric furnaces. To improve your operation, look to General Electric, a pioneer in the development of better industrial heating equipment. G-E service facilities are unmatched by any other heating equipment manufacturer. For application help from a G-E Heating Specialist, contact your G-E Apparatus Sales Office.

GENERAL ELECTRIC

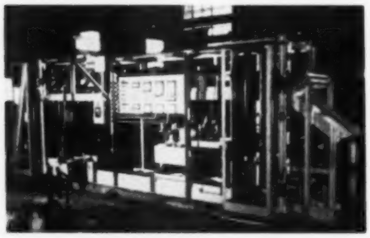
WRITE NOW FOR THESE MODERN METAL PROCESSING BULLETINS

- Furnace and Induction Brazing, GEA-5889
- Annealing Malleable Iron, GEA-5797
- Forging with Induction Heat, GEA-5983
- Heat-treating Aluminum, GEA-5912

Address: General Electric Co., Section 720-128, Schenectady 5, N. Y.

Casting Machine

Ferguson Equipment Corp.'s tray-cast machine is a production casting, molding or forming unit on which trays or molds can be removed easily, permitting pouring molds of several kinds at the same time, rapid replace-



ment of imperfect molds and quick changeover in production. The unit consists of one or more pouring stations, pushers and elevators which move the trays through a cooling chamber and knockout hammer, and an ejector. The machine requires one-half of the floor space required by similar conveyor-type casting machines since both top and bottom lines can be poured at all times, and usually the machine need not be placed in a pit. It is suitable for casting aluminum, brass, copper, tin and lead, and can be built in capacities from 1000 to 10,000 lb. per hr. of aluminum, and higher for heavier metals.

For further information circle No. 895 on literature request card, p. 36-B.

Titanium Fasteners

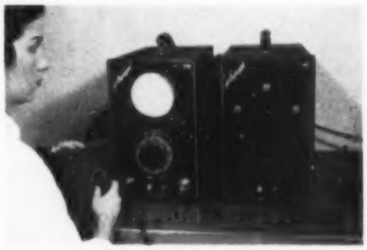
Elastic Stop Nut Corp. of America has announced production of the first commercially-available titanium locknuts. Made of high-strength titanium alloy, these nuts will meet AN tensile strength requirements for steel nuts of the same thread size, but will weigh less than half as much as steel hex nuts. First production will be of 12-point (double hex) nuts with nylon locking collars, in sizes from 5/16 to ⅝. Other types will be added later. A special permanent coating developed for these nuts will reduce seizing and galling to a minimum. Republic Aviation Corp., which is conducting extensive investigation of titanium aircraft components, has estimated that substitution of titanium for steel in aircraft fasteners could save as much as 213 lb. on a fighter plane. This might amount to a saving of more than a ton of overall weight since engineers figure every pound saved in design structural weight enables reduction of overall weight by about 10 lb.

For further information circle No. 896 on literature request card, p. 36-B.

Testing and Sorting

Nondestructive testing and sorting of accidentally mixed or incorrectly processed metal parts can be done rapidly by the new Model C-1 Cyclograph. The instrument can be used on either ferrous or nonferrous metals and will sort raw stock, semifinished, or finished parts by their metallurgical characteristics such as analysis, hardness, structure and case depth. With a known and acceptable part used as a "standard" in adjusting the instrument, unwanted parts are quickly separated from the good ones.

Model C-1 can be used as a "hand" sorter, in which case the operator watches the screen and manually throws out the off-standard parts, or

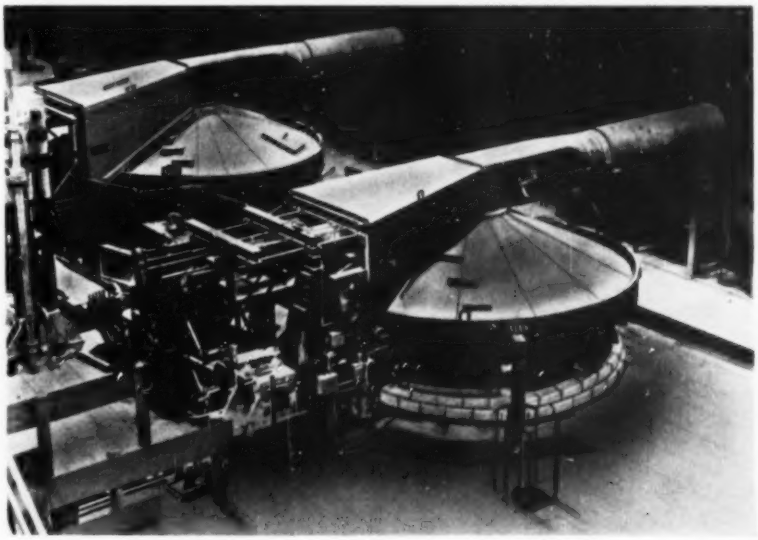


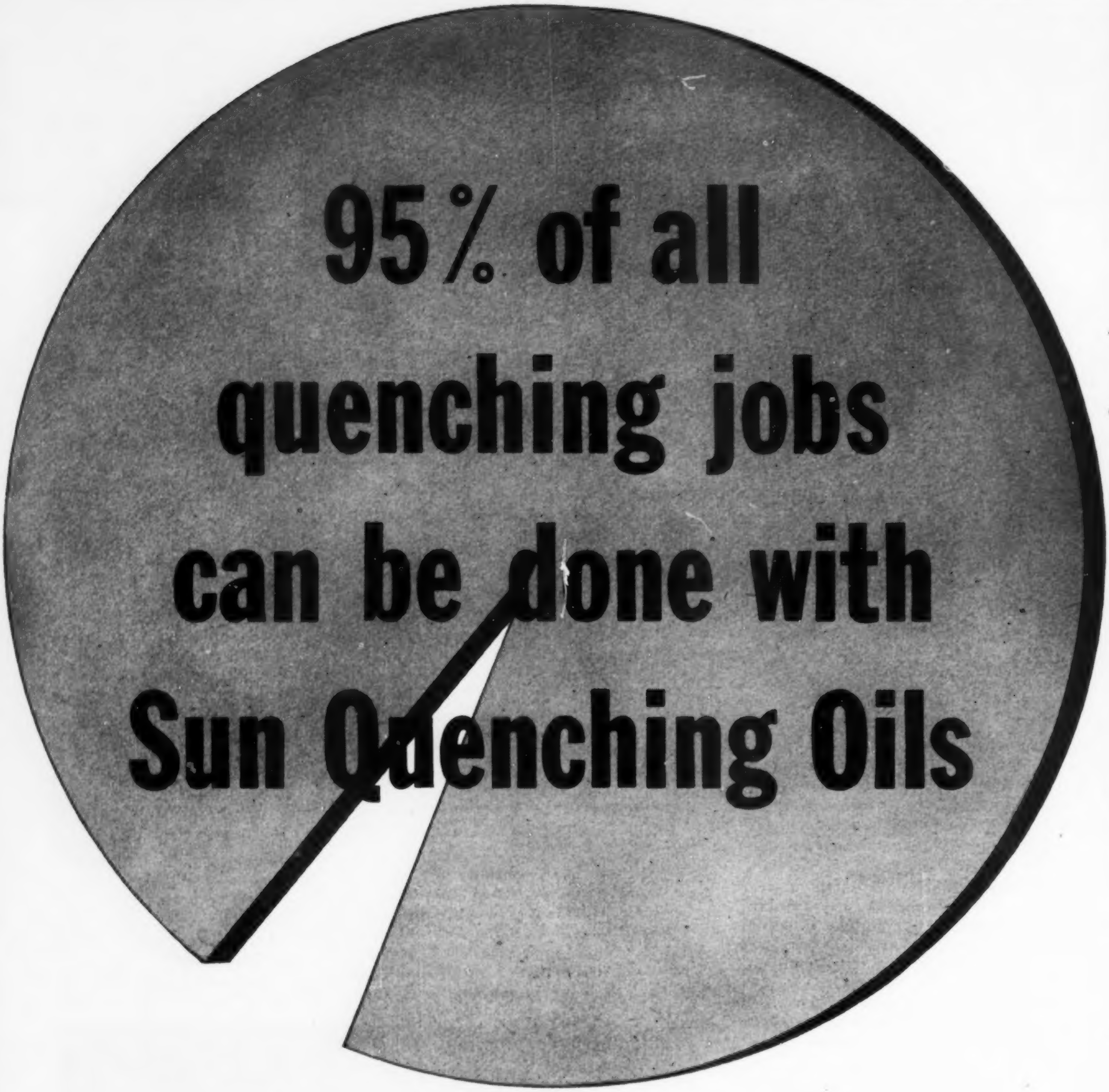
it can be used in conjunction with an automatic relay unit, which eliminates operator discrimination and makes it possible to sort many more thousands of parts per day. Parts can be passed through the test coil on a belt conveyor or by other fast feeding means. The relay unit sends out a reject signal whenever an off-standard part

Salt Bath Furnace

Electric salt bath units designed to heat stainless steel billets of 300 and 400 series prior to hot extrusion have been designed by Ajax Electric Co. for Allegheny Ludlum Steel Corp. The 2300° F. molten baths are an integral part of the Ugine-Sejournet process. Scaling, oxidation and decarburization are avoided because all atmosphere is eliminated in the bath, and a protective film of salt prevents scaling and reduces friction in the extrusion press. It takes 25 min. to heat a 5¼-in. round from room temperature to 2300° F.

For further information circle No. 897 on literature request card, p. 36-B.





. . . AT MUCH LOWER COST

For 95% of your quenching jobs, you don't have to use expensive compounded oils. Sun's low-cost quenching oils will give the same uniform results, assure fast and thorough quenching, help increase production and lower maintenance. The booklet "Sun Quenching Oils" tells the complete story. For your copy, call your nearest Sun office or write SUN OIL COMPANY, Philadelphia 3, Pa., Dept. MP 4.

INDUSTRIAL PRODUCTS DEPARTMENT

SUN OIL COMPANY

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passes through the test coil and this signal can be used to operate a solenoid reject gate, paint spray marking device or other reject means. The combination permits fully automatic, highspeed inspection.
For further information circle No. 898 on literature request card, p. 36-B.

Grinding Wheels

The Carborundum Co. has announced its new Carboflex depressed-center grinding wheels for rough grinding, weld removal, cutoff and slotting operations for ferrous and

nonferrous metals and nonmetallics. Designed with a knurled back in addition to the knurled face, the new wheels enable the operator to cut with both sides and the periphery of the wheel without any initial dressing. The new wheels come in sizes of 7 and 9⅛ in. in diameter, ⅛, 3/16 and ¼ in. in thickness, with a ⅞ in. arbor.
For further information circle No. 899 on literature request card, p. 36-B.

Atmosphere Testing

The Electric Furnace Co. has introduced a new portable, visual unit for testing atmosphere in heat treat-

ing furnaces. The tester may be used to determine carbon potential and also to detect the presence of sulphur, which usually is detrimental to bright annealing treatments. To make a test, the operator clamps a strip of metal, similar in composition to the metal being heat treated, between two electrodes visible within a Pyrex tube, so that the metal becomes a resistor in a circuit. The temperature of the specimen is controlled with a rheostat. The gas atmosphere to be tested is then supplied to the Pyrex tube. The temperature of the specimen is raised to the temperature of the metal in the furnace and held for the desired length of time; then the atmosphere is cooled to the critical temperature at which the metal would discolor in the gas atmosphere being tested, thus establishing the length of time for the metal to pass through the critical range to prevent discoloration.
For further information circle No. 900 on literature request card, p. 36-B.

Coolant Tank

The largest industrial coolant tank in the world is now en route from the United States Hoffman Machinery Corp., to the Ford Motor Co., where it will be used to reclarify quench oils. The 18,000-gal. capacity of the huge oil clarifier is enough to hold the entire contents of two railroad tank cars. The separator removes 75 to 90% of ferrous solids. It is designed for continuous operation, is fully automatic and self-cleaning. It eliminates cleaning of sumps and changing of filter papers, bags or cartridges. The big separator consists of three basic parts—the tank itself, the Magnaflow plate, and the sludge scraper mechanism. The Magnaflow

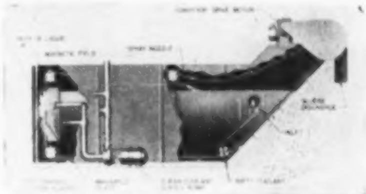


plate containing shielded Alnico permanent magnets, is suspended below the oil level.
For further information circle No. 901 on literature request card, p. 36-B.

Joining of Aluminum

Utica Drop Forge & Tool Corp. has announced the new Koldwelding tool for the lap welding of aluminum sheet or foil without heat or electricity and without flux or chemical of any kind. It is hand operated and accomplishes the welding of aluminum foil, sheet, shaped extrusions or strip by pressing the surfaces of the parts together between specially designed dies. To prepare the metal surfaces for the weld it is merely necessary to clean them with a steel wire scratch brush (or similar mechanical action).

The tool will join aluminum and electrical copper in thicknesses 0.001 to 0.040 in., or an over-all maximum thickness of 0.080 in. Each thickness of material requires a different size

interchangeable die. The KL-10 handles all types of aluminum (except 56S and aircraft qualities in the T temper) and electrical copper. Welds meet the same tests as applied to conventional welds. When the weld is pulled apart fracture occurs around the periphery of the spot, pulling a slug from one of the sheets.

For further information circle No. 902 on literature request card, p. 36-B.

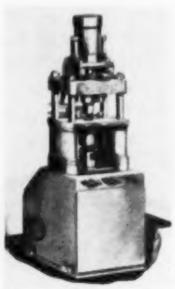
Finish

Plextone, a new color-flecked finish produced by Maas & Waldstein Co., is a patented enamel that combines warmth of texture, richness of multicolor and durability in one spray application from one gun in one coat that completely covers surface flaws and blemishes. The product has been used for finishing displays and racks, kitchen cabinets, machinery, office panels and partitions, furniture, store fixtures, switch gear housings, table lamps and shades.

For further information circle No. 903 on literature request card, p. 36-B.

Compacting Press

A new 50-ton powdered metal compacting press has been announced by Baldwin-Lima-Hamilton Corp. The Model "L" is a mechanical, four-column, crank-type press equipped with flywheel, pneumatic clutch and pneumatic brake, and is driven by a 10-hp. motor. Adjustment for changes in compacted-part density or weight can be made while the press is in operation. Special features are a hydraulic head assuring control of pressure being applied, a floating die holder and core rod, fill adjustment, prepressing die position control, shuttle-type feeder, automatic lubrication and cycling for continuous run, semicontinuous run, single stroke and inching.



For further information circle No. 904 on literature request card, p. 36-B.

Low-Temperature Chambers

New low-temperature units for producing temperatures to —170° F. have been announced by Tenney Engineering. They are equipped with special

rotary compressors designed for use with latest Freon refrigerants. Available with 1, 4, 6, 9 and 12 cu. ft. work space, chambers in all five sizes produce temperatures to —40, —80, —100 and —120° F. All but the 1-cu. ft. model produce temperatures to —150 and —170° F. They are de-

"We test all our rolls

with a Penatrascope"

—says Kenneth Strang,

U. S. STEEL INSPECTOR

THIS new portable hardness tester was specifically developed to eliminate the human error in measuring steel hardness. It's so new that few people have ever seen one in action. As far as we know, we are the first manufacturer in this country to use it for testing forged steel work rolls as Kenneth Strang, U. S. Steel Inspector for eighteen years, is doing in our Homestead Forgings Division.

Here's how this ultraprecise instrument works. A minute diamond point is pressed into the steel under accurately controlled pressure and a calibrated microscope measures the tiny indentation. This measurement can be made to an accuracy of .001 millimeters—about forty millionths of an inch—and provides one of the most exact checks on the hardness of steel yet developed.

Why do we use an instrument of such accuracy in checking our cold reduction mill rolls? The answer is simple. The quality of these rolls is of paramount importance to mill superintendents and the men responsible for roll maintenance. Therefore, they are a premium product with us and they are treated as such in every step from the electric furnace ingot to the finished product. So, when it comes to the highly important matter of hardness, Kenneth Strang relies on the most modern instruments to obtain readings of indisputable accuracy.

We have a free 32-page booklet that describes USS Quality Forgings. It's interesting, and describes the steel, the equipment and the men who make USS Quality Forgings for you. Address United States Steel, Room 4298, 525 William Penn Place, Pittsburgh 30, Pa.

USS

Quality

FORGINGS

heavy machinery parts—carbon, alloy, stainless

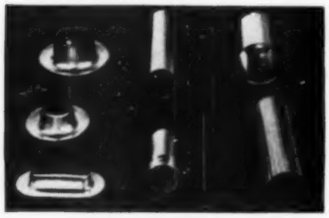
forged steel rolls and back-up roll sleeves

electrical and water wheel shafts

hammer bases and columns

Loads are easily handled in the Steam Homo Furnace.

STEAM ATMOSPHERE HEAT TREATMENT *is becoming standard for many high speed steel cutting tools. It's effective for tools machining average jobs . . . is even better for treating tools handling tough jobs, such as working high-chrome, high-carbon steels.*



COST CUTS OF 53% *. . . in annealing and pickling, effected through steam-atmosphere annealing of these brass stampings.*

For full information about Steam Homo tempering, send for the NEW 12 page catalog, "L&N Steam Homo Method for Heat-Treating". Write our nearest office, or 4927 Stenton Ave., Phila. 44, Pa.

Want Heat-Treating Versatility?

CHECK THESE STEAM HOMO® ADVANTAGES

You get many outstanding heat-treating advantages when you buy the versatile Steam Homo furnace. Here's why:

- Steam Homo gives you scale-free heat-treating of both ferrous and non-ferrous parts at temperatures to 1150 F.

If you're heat-treating ferrous parts:

- The tough oxide film that Steam Homo imparts adds 20–25% more life to high-speed tool steels.
- Steam-treating adds appreciably to the hardness and compressive strength of powdered iron compacts.

Or if you're heat-treating non-ferrous parts:

- Steam atmosphere in many cases eliminates subsequent surface cleaning and pickling operations.

But in both cases you'll get:

- A compactness which makes the Steam Homo equipment ideal for installation directly in production lines.
- A steam atmosphere heat-treating process which is entirely safe and easy to follow.

Standard Steam Homo furnaces are made in a variety of sizes . . . from those with work spaces as small as 11½" x 15" to those as large as 28" x 60". All are supplied as assembled units, ready for installation.

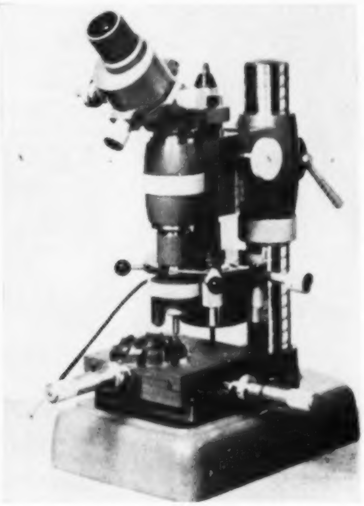
LEEDS & NORTHRUP

instruments *automatic controls • furnaces*

signed for quick pull-down (approximately 2 to 3 hr.), and an indicating controller automatically maintains pre-set temperatures.
For further information circle No. 905 on literature request card, p. 36-B.

Micro Hardness

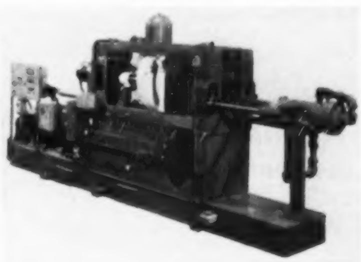
A hardness testing instrument that makes minute impressions, which cannot be seen with the naked eye and do not mar even the finest finish, is available from George Scherr Co., Inc. It is a portable bench-type instrument in which the microscope is swung



directly over the impression to read the hardness by measuring with a reticule scale and vernier in 0.0005 mm. (half a micron) at a magnification of 400. Coarse impressions such as those from Brinell ball can also be measured, for which purpose a coordinate measuring stage is provided such as found on toolmakers' microscopes.
For further information circle No. 906 on literature request card, p. 36-B.

Die Casting Machine

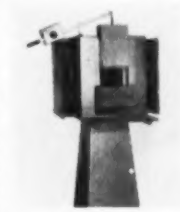
Lester-Phoenix, Inc., has announced a new die casting machine designed to cast up to 4⅞ lb. of aluminum or proportional weights of magnesium or



brass. It will accommodate dies up to 25 by 22 in. The machine has a positive toggle clamping pressure of 200 tons. With the patented central die height adjusting screw, dies can be set to open a fraction of a thousandth of an inch at full clamp, taking complete advantage of the full locking pressure and still getting venting. The machine is readily converted to zinc casting.
For further information circle No. 907 on literature request card, p. 36-B.

Silicon Carbide Furnace

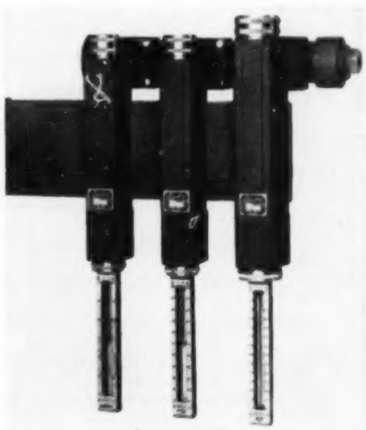
The Sentry Co. have announced improvements in their high speed steel hardening furnaces, including close regulation of heat at the operating range, rapid heating to desired temperature and generally greater operating economy. Silicon carbide resistors located



above and below the one-piece silicon carbide muffle chamber supply the heat. Heating elements and terminals are readily accessible on each side of the furnace and are protected. The unit is designed specifically to permit use of atmospheric control.
For further information circle No. 908 on literature request card, p. 36-B.

Flow Meter

A device for precision measurement of carrier, enriching gas and ammonia in the carbonitriding processes has been announced by Waukee En-



gineering Co. The unit can be used with any type of furnace properly designed for carbonitriding and for controlling carrier and enriching gas for straight carburizing. Control valves are built into the top of each flow meter. The unit includes a mixing manifold with 1¼-in. outlet connections at both ends, so that piping can be brought from either side.
For further information circle No. 909 on literature request card, p. 36-B.

WHAT'S NEW IN MANUFACTURERS' LITERATURE

936. Allowable Stresses
Data Card 154 gives max. allowable stress values for 22 types of steel tubing. Formulas for calculation of max. working pressures. *Babcock & Wilcox*

937. Alloy Castings
Data folders on two types of alloy steel castings. Composition, properties, hardenability bands, uses. *Unitcast*

938. Alloy Castings
8-page bulletin on alloy castings for heat treating. *Ohio Steel Foundry*

939. Alloy Steel
32-page book on abrasion resisting steel. Properties, fabricating characteristics, uses. *U. S. Steel*

940. Alloy Steel
Data book on the selection of the proper alloy steel grades for each manufacturer's needs. *Wheelock, Lovejoy*

941. Alloy Steel
16-page book on type 9115 low-alloy high-strength steel. Properties, fabrication, welding. *Great Lakes Steel*

942. Alloy Steel
68-page "Aircraft Steels" book includes revised military specifications. Also stock list. *Ryerson*

943. Alloy Steel Machining
12-page "Relation of Machining Time to Material Cost". Comparative machinability costs per ton for eleven steels. *La Salle Steel*

944. Aluminum Die Castings
Bulletin on design and manufacture of aluminum die castings. *Hoover Co.*

945. Aluminum Extrusions
Data on services in the field of aluminum extrusions. *Himmel Bros. Co.*

946. Ammonia for Heat Treat
Booklets on "Applications of Dissociated Ammonia", "Ammonia Installations for Metal Treating", "Nitriding Process", "Carbonitriding". *Armour*

947. Analysis of Metal
Folder on spectrochemical analysis service. *Chicago Spectro Service Lab.*

948. Annealing Furnaces
8-page illustrated booklet on continuous annealing furnaces. Schematic diagrams, photographs, and actual production data. *Drever*

949. Arc Welding
44-page catalog describes over 20 models of arc-welding machines, with sections on accessories and electrodes. *Air Reduction*

950. Atmosphere Control
Bulletin No. AD-609 on providing an inert, oxygen-free furnace atmosphere through proper instrumentation and procedure. *Arnold O. Beckman*

951. Atmosphere Furnace
Information on mechanized batch-type atmosphere furnaces for gas cyaniding, gas carburizing, clean hardening or carbon restoration. *Dow Furnace*

952. Atmosphere Furnace
Bulletin on vertical muffle-type furnace for heat treatment of practically all types of steel. *Surface Combustion*

953. Automatic Polishing
14-page, illustrated brochure describes automatic equipment for polishing, buffing and grinding. *Murray-Way*

954. Barrel Finishing
32-page handbook on compounds for descaling, deburring, coloring, metal cleaning and rust inhibition. *Lord Chem.*

955. Basic Materials
24-page booklet on Alundum, Crystolon, Magnorite, Norbide, zirconia, carbides, borides and other basic materials. Products made from them are listed. *Norton*

956. Bending
Catalog on presses for bending, forming, blanking, drawing and multi-punching. *Cleveland Crane & Engineering*

957. Bending and Cutting
Folder describes hand and air-operated bender-cutter and its applications. *J. A. Richards*

958. Beryllium
20-page booklet describes beryllium products, including the pure metal, oxide and alloys. *Beryllium Corp.*

959. Bimetal Applications
36-page booklet, "Successful Applications of Thermostatic Bimetal", describes 22 uses and gives engineering data. *W. M. Chace*

960. Black Oxide Coatings
Data on black oxide coatings for steel, stainless steel and copper alloys. *Du-Lite*

961. Blackening Stainless
Bulletin on process for blackening stainless steels, cast and malleable irons. *Mitchell-Bradford*

962. Blowers
Bulletin 100-53 on combustion air blowers of 8 to 20 oz. pressures. *Western Products*

963. Boron Additive
6-page article on use of grainal as boron-additive alloy and properties of grainal steels. *Vanadium Corp.*

964. Brazing
50-page text GEA-3193 describes the methods and applications of electric-furnace brazing. *General Electric*

965. Brazing Applications
48-page manual on all aspects of silver brazing applications and problems. *American Platinum Works*

966. Brazing Stainless Steel
Illustrated booklet, "Bright Annealing, Hardening and Brazing Stainless Steel", describes conveyor furnace and bright brazing alloy. *Sargeant & Wilbur*

967. Brazing Titanium
Data sheet on use of a new flux for brazing titanium. *Handy & Harman*

968. Bronze Bearings
New brochure on bearing bronze. *American Smelting & Refining*

969. Bulb Thermometers
44-page catalog covers selection data, recorders and indicators, controls, psychrometers, bulbs, tubing and fittings. *Minneapolis-Honeywell*

970. Burners
Bulletin 123 on new series of burners for multi-purpose furnaces. *North American Mfg.*

971. Carbide Segregation
Effect of carbide segregation in tool steel. *Latrobe Steel*

972. Carbon Control
Catalog T-623 describes the Microcarb control system that continuously measures the active carbon in the furnace atmosphere during heat treatment. *Leeds & Northrup*

973. Carbon Control
Technical report on instrument for control of carbon potential of furnace atmospheres. *Lindberg Eng'g*

935 Shell Molding

Principal topics discussed in this 40-page book on shell molding are: the patent status, the process, patterns, gates, runners, risers, ejection, sand,

resins, fillers, operating temperatures, lubricants, assembly for pouring, cores, cost, properties, mold defects and their causes and remedies, shell mold machines. *Durez Plastics & Chemicals*

974. Carbon Steel
Specifications, chemical analysis, properties, heat treatment of Empire carbon and low-alloy steel castings. *Empire Steel Castings*

975. Carburizing
Data folder on Aerocarb E and W water-soluble compounds for liquid carburizing. Case depth vs. time curves. Per cent carbon and nitrogen penetration curves. *American Cyanamid*

976. Carburizing
Bulletin on non-burning carburizers. *Park Chemical*

977. Carburizing
Bulletin on deep case liquid carburizing. *Park Chemical*

978. Carburizing
16-page bulletin SC-134 reviews gas carburizing techniques and possibilities. *Surface Combustion*

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Folder on salts for liquid carburizing. *Swift Industrial Chemical*

980. Casehardening
32-page booklet on casehardening of steel by nitriding. *Armour Ammonia Div.*

981. Castings, Bronze
16-page booklet on sand and centrifugal castings. *Amer. Non-Gran Bronze*

982. Centrifugally Cast Pipe
130-page book on centrifugally spun steel tubes. Specifications, physical requirements, chemical analyses. *American Cast Iron Pipe Co.*

983. Ceramics
Bulletin on general design principles for ceramics gives electrical and mechanical properties. *Frenchtown Porcelain*

984. Chromate Coatings
Folder gives characteristics and uses of chromate conversion coatings on nonferrous metals. *Allied Research*

985. Chromium Cast Iron
48-page book on effects of chromium on properties of cast iron. Data on production and uses. *Electro Metallurgical*

986. Clad Metals
24-page booklet on principles of bonding, characteristics of clad metals, methods of cladding and applications. *Superior Steel*

987. Cleaner
Folder gives data on metal cleaners for use with water in still-tank or spray-washing equipment. *Solventol*

988. Cleaners
Series of bulletins on seven emulsion cleaners for a variety of purposes and uses. *Turco Products*

989. Cleaning
Story of automatic cleaning operations at Ford Engine Plant. *Metalwash Machinery Corp.*

990. Cleaning
24-page booklet on use of solvent detergents for removing carbon, grease, dirt and paint. *Oakite*

991. Cleaning
6-page bulletin includes concentrations for various metal cleaning applications and a handy list of cleaners for general industrial use. *E. F. Houghton*

992. Cleaning Aluminum
12-page bulletin on cleaning process for preparing aluminum and magnesium for welding. *Northwest Chemical*

993. Combustion Control
20-page booklet on combustion of various fuels and portable instrument to measure content of oxygen and combustibles. *Cities Service Oil*

994. Compressors
12-page Data Book 107-C gives engineering information on characteristics of turbo-compressors. 18 types of application described. *Spencer Turbine*

995. Continuous Filtration
Bulletin on equipment for automatic skimming and continuous filtration for paint spray booth water. *Industrial Filtration*

996. Controlled Atmospheres
24-page bulletin describes production problems with reference to dry atmospheres. *Pittsburgh Lectrodryer*

997. Controlled Atmospheres
Bulletin 753 on generator for atmospheres for hardening, brazing, sintering and annealing carbon steels. *Hevi Duty*

998. Coolants
Bulletin on recommended coolants and lubricants for tungsten carbide cutting tools and drawing dies. *Metal Carbides*

999. Copper Alloys
40-page book on eleven copper alloys. Properties, cleaning, annealing. *Seymour Mfg.*

1000. Copper Alloys
40-page handbook on phosphor bronze nickel silver, cupro nickel, berylliun copper. *Riverside Metal*

1001. Corrosion of Copper
28-page booklet B-36 discusses corrosive attack on copper and copper alloys. Tabulation of their relative corrosion resistance. *American Brass*

1002. Corrosion Resistance
32-page brochure on causes of corrosion and means of combating them. Choice of materials for condenser tubes. *Revere Copper & Brass*

1003. Corrosion Resistance
35-page booklet on plastic materials of construction. *Atlas Mineral Products*

1004. Corrosion Resistance
New chart indicates resistance of seven classes of corrosion resistant cements to 297 of the most generally used corrosive chemicals. *Pennsylvania Salt*

1005. Corrosion Resistant Alloy
Data sheet compares corrosion properties of Elgiloy and stainless steel. *Elgin National Watch Co.*

1006. Cut-Off Wheels
Folder gives data, operating suggestions and grade recommendations of cut-off wheels. *Manhattan Rubber Div.*

1007. Cutting Oil
Folder on sulphurized cutting fluid for a wide range of machining jobs. *Gulf Oil*

1008. Cutting Oil
Shop notebook gives important facts on right cutting fluid for any machining operation. *D. A. Stuart*

1009. Decarb Test
Simple test for decarburization described in Tips and Trends. *Ajax Electric*

1010. Deep Drawing
Reprint on new deep drawing technique involving single-stroke dies and eliminating intermediate operations. *Schnell Tool & Die*

1011. Degreasing
34-page booklet on vapor degreasing. Design, installation, operation and maintenance of equipment. *Circo Equipment*

1012. Degreasing
Pamphlet on properties and use of trichlorethylene. *Niagara Alkali*

1013. Die Castings
Booklet on small zinc die castings. For designers and engineers. *Gries Reproducer Corp.*

1014. Die Sets
New catalog shows complete line of ball bearing die sets. *Lempco Products*

1015. Die Steel
Data on air hardening, free machining die steel. *Latrobe Steel*

1016. Drawing Compounds
Folder on lubricant for forming and drawing of stainless. *Hangsterfer*

1017. Dust Collector
Bulletin on cloth bag dust collector for indoor use. *Pangborn*

1018. Electric Furnaces
Booklet on four types of electric heating elements and methods of mounting them. *Holcroft*

1019. Electric Furnaces
Brochure on electric heat treating, melting, metallurgical tube, research and sintering furnaces. *Pereny Equipment*

1020. Electropolisher
Bulletin on theory and practice of electrolytic polishing of metallurgical samples. Description of electropolisher. *Buehler*

1021. Fatigue of Magnesium
18-page paper, "Plastic Flow and Work Hardening Phenomena in Magnesium Alloys During Fixed-Deflection Fatigue Tests". *Dow Chemical*

1022. Filters
8-page bulletin on dimensions and capacities of industrial filters. *Industrial Filtration Co.*

1023. Finishing
Catalog A-654 gives complete story on planning industrial finishing systems and shows many installations of cleaning and pickling machines. *R. C. Mahon*

1024. Finishing
28-page catalog B-9 on corrosion-resistant baskets, racks, crates and tanks and other fixtures for cleaning and finishing. *Rolock*

1025. Finishing
52-page booklet on deburring and finishing equipment, and barrel finishing. *Almco*

1026. Flame Cutting
12-page booklet on use of automatic flame cutting in the making of machinery weldments. *Air Reduction Sales*

1027. Flaw Detection
Illustrated bulletin on Spotcheck, new dye-penetrant method for locating surface defects. *Magnaflux*

1028. Flow Meters
Bulletin 201 on flow meter for gas used in heat treating. *Waukee Eng'g.*

1029. Fluid Selector
Cutting and grinding fluid selector for various machining operations. *D. A. Stuart*

1030. Forged Shapes
Catalog of smooth hammered forgings, composite die sections and cast-to-shape tool steels. *Forging & Casting Div., Allegheny Ludlum*

1031. Forgings
Handsome 32-page brochure on large forgings for turbine shafts, rotors, drop hammer anvils, rolls. *U. S. Steel*

1032. Forgings
32-page engineering manual of brass and aluminum forgings. *Mueller Brass*

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Folder on styles of forming dies for stainless heads—in wide range of sizes and gages. *Carlson*

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Bulletin on machinery and equipment for cold roll forming. *American Roller Die*

1036. Foundry Coatings
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1038. Furnace Belts
44-page catalog describes metal belts for quenching, tempering, carburizing and other applications. *Ashworth Bros.*

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12-page brochure on eight models of charging machines for heating and melting furnaces. *Salem-Brosius*

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Data sheet on instrumentation for measurement and control of temperatures during heat-up of openhearths and other high-temperature furnaces. *Minneapolis-Honeywell*

1041. Furnace Controls
Bulletin on instruments and controls for heat treating furnaces. *Hays Corp.*

1042. Furnaces
Booklet on electric furnaces with zone control between 500 and 2300° F. *L & L Mfg.*

1043. Furnaces
High temperature furnaces for temperatures up to 2000° F. are described in bulletin. *Carl-Mayer Corp.*

1044. Furnaces
Bulletin D on salt pot furnaces, forging furnaces, melting furnaces and others. *Eclipse*

1045. Furnaces
Bulletin describes 18 electric furnaces for research and small-scale production, with operating temperatures to 3000° F. *Harper Electric Furnace*

1046. Furnaces
12-page brochure on car furnaces of special and conventional design. *Jet Combustion*

1047. Furnaces, Heat Treating
Bulletin on fuel and electric furnaces for heat treating. *Dempsey*

1048. Furnaces, Heat Treating
Catalog on furnaces for tool room and general purpose heat treat. *Cooley*

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32-page catalog on high-speed gas furnaces for heat treating carbon and alloy steels; also pot furnaces for salt and lead hardening. *Charles A. Hones*

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1052. Gages
Data on X-ray diameter gage for hot rolled rod and X-ray gage for pipe wall thickness measurement. *Industrial Gauges*

1053. Galvanizing
Reprint "Modern Hot-Dip Galvanizing" deals with dross formation as a cause of zinc waste. Detailed information on zinc ammonium chloride type of flux. *Hanson-Van Winkle-Munning*

1054. Gas Analysis
Data on positive, nondispersion-type infrared analyzers for laboratory and industry. *Minneapolis-Honeywell*

1055. Gas Carburizing
Bulletin on gas carburizing in rotary furnaces. *American Gas Furnace*

1056. Gold Plating
Article on analysis of gold and gold alloy plating solutions gives all currently available procedures. *Technic*

1057. Graphite Electrodes
Vest-pocket notebook containing 90 pages of information on electric furnace electrodes and other carbon products. *Great Lakes Carbon Corp.*

1058. Graphitic Tool Steels
48-page booklet on heat treating data, properties and 46 specific applications of graphitic tool steel. *Timken*

1059. Grinding Magnesium
Data on how to grind and polish magnesium alloys includes grinding wheel recommendations, procedures, dust collection and safety precautions. *Norton*

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Pamphlets on clamps for lifting and handling. Their application to various industries. *Merrill Bros.*

1061. Hard Surfacing
40-page hardfacing manual tells what metals can be hardfaced, how to select right hardfacing material, lists step-by-step procedures and industrial applications. *Haynes Stellite*

1062. Hardening Gears
How gears are carburized and martempered at Jack & Heintz. *Ajax Electric*

1063. Hardness Tester
Bulletin ET 469 on new portable hardness tester. *Newage International*

1064. Hardness Tester
Literature on Brinell testing machines. *Detroit Testing Machine Co.*

1065. Heat Resistant Castings
New Bulletin No. 5 on heat and corrosion resisting pots, tubs, boxes. *Standard Alloy*

1066. Heat Treating
Reprint on "Heat Treaters Cite Short Cuts to More Effective Purchasing". *Metal Treating Institute*

1067. Heat Treating
Bulletin describes baskets, crates, trays, furnace parts for heat treating. *Stanwood*

1068. Heat Treating
Discussion of process for heat treating projectile billets in Metal Minutes for December. *Sunbeam Corp.*

1069. Heat Treating
56-page "Heat Treating Alloy Steels". *Republic Steel*

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72-page catalog on carburizing, cyaniding, brazing, austempering and annealing processes. *Ajax Electric*

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Bulletin on wire mesh baskets for heat treating and plating. *Wiretex Mfg.*

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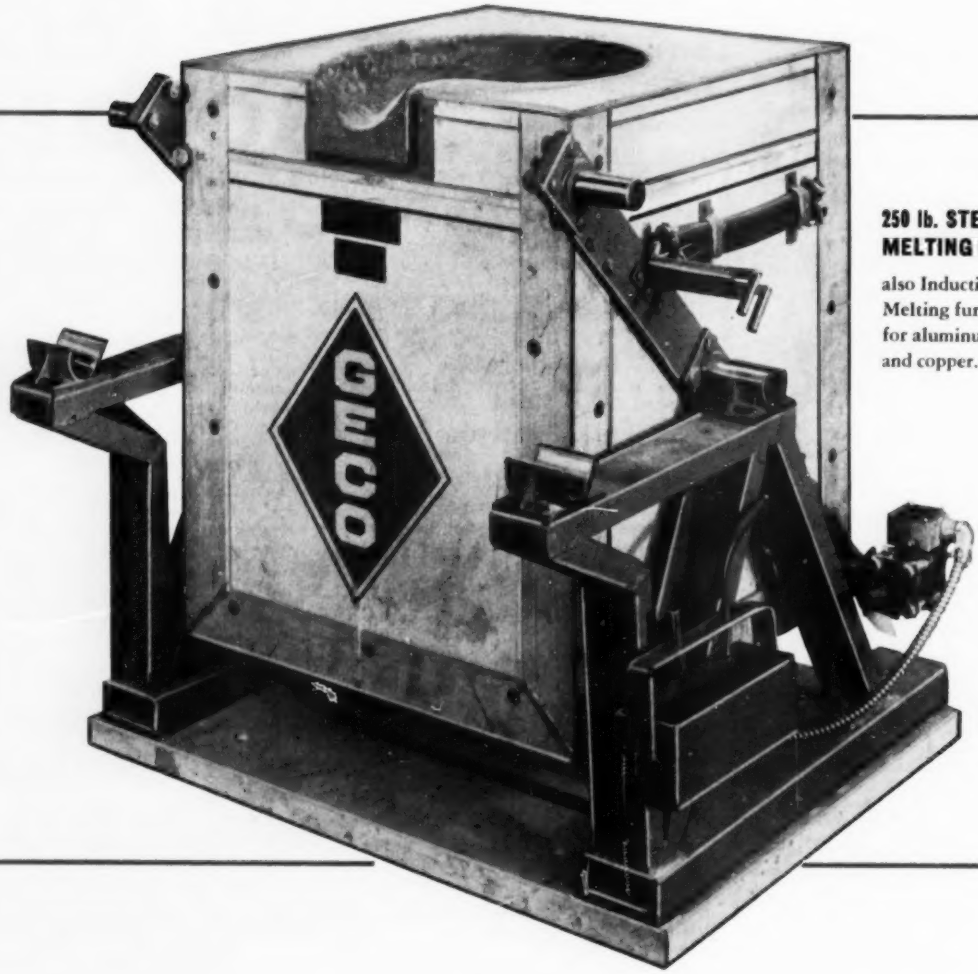

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1075. High-Alloy Castings
Bulletin 3150-G on castings for heat, corrosion, and abrasion resistance. *Duraloy*

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12-page booklet on fabrication and design data for stainless 330 (35% Ni-15% Cr) and other alloys. *Rolled Alloys*

1077. High-Temperature Alloy
Property data for 21% Cr, 9% Ni heat-resistant alloy. *Electro-Alloys Div.*

1078. High-Temperature Alloys
High temperature work sheet provides valuable suggestions for solving high temperature problems in design and production. *International Nickel*

1079. High-Tensile Steel
Bulletin on nickel-copper steel of low-alloy, high-strength type. *Youngstown Sheet and Tube*

1080. Identifying Alloys
Booklet on procedures for rapid identification of more than 125 metals and alloys. *International Nickel*

1081. Impregnation of Castings
Literature on new impregnating equipment for elimination of porosity in ferrous and nonferrous castings. *Metallizing Co. of America*

1082. Induction Furnaces
Data on induction melting furnaces for aluminum, brass and copper. *Morrison Engineering*

1083. Induction Heating
Bulletin on new 60-cycle induction furnace for heating aluminum, magnesium, copper and brass for forging, extrusion and rolling. *Loftus Eng'g*

1084. Induction Heating
Bulletin on low-frequency (60-cycle) induction heating furnace for nonferrous metals. *Magnethermic*

1085. Induction Heating
12-page bulletin 5679 on induction hardening, brazing, annealing at 1000, 3000, and 10,000 cycles. *General Electric*

1086. Induction Heating
60-page catalog tells of reduced cost and increased speed of production on hardening, brazing, annealing, forging or melting jobs. *Ohio Crankshaft*

1087. Induction Heating
"Induction Heating" . . . presents case histories of increased production, reduced space, lower costs. *Westinghouse*

1088. Industrial Furnaces
Booklet 127 on furnaces, ovens, dryers, and special automatic machines for industry. *Continental Industrial Engineers*

1089. Inspection
Data on conveyorized auxiliary unit which may be used with standard Magnaflux for rapid production inspection. *Magnaflux*

1090. Instruments
Bulletin F-5633-1 on instruments for industrial process control. *Wheelco*

1091. Iron-Nickel Alloys
32-page bulletin on austenitic iron-nickel alloys having special thermal expansion or thermo-elastic characteristics. *International Nickel*

1092. Laboratory Equipment
Booklet on better laboratory planning. Section on recommended bidding practices. *Scientific Apparatus Makers Assoc.*

1093. Laboratory Furnaces
Data sheets on complete line of laboratory furnaces for metallurgical operations. *Boder Scientific*

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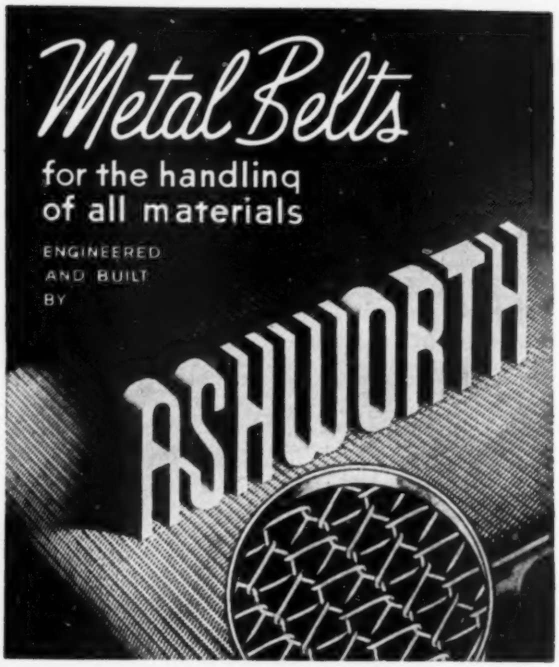

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16-page booklet on use of aluminum and magnesium in product design. *Rolle Mfg.*

1095. Liquid Level Control
Bulletin on electronic and magnetic controllers which are independent of pressure, temperature, acids, salts. *Ferrara*

1096. Low-Alloy Steel
60-page book on high-strength low-alloy steel, properties, fabrication and uses. *U. S. Steel*

1097. Low Temperature Properties
Article on application of extreme low temperatures to metallurgy. Behavior of metals at low temperatures. *Arthur D. Little*

1098. Lubricant
8-page folder describes use of molybdenum disulfide lubricant in cold forming, cold heading and other applications. Case histories. *Alpha Corp.*

1099. Lubricant
New literature on anti-seize molybdenum disulfide lubricant. *Bel-Ray*

1100. Lubrication
24-page illustrated bulletin gives history of 100 years progress in cutting oils, core oils and lubricants. *Swan-Finch Oil*

1101. Magnesium
Dimensions, analyses, property data of magnesium plate and sheet. *Brooks & Perkins*

1102. Magnesium Finishing
128-page book describes all methods for finishing magnesium. *Dow Chemical*

1103. Magnetic Alloys
6-pages of data on Curie temperature of many alloys and how this phenomenon is of importance. *International Nickel*

1104. Magnetism
Data on magnetism in stainless steel castings, its importance in chromium and chromium nickel castings and wrought alloys. *Empire Steel Castings*

1105. Malleable Iron
Reprint 51-B on metallurgy, treatment, and heat treated properties of malleable iron. *Surface Combustion*

1106. Mechanical Cleaning
Booklet on how brushes are used for cleaning welds, stainless sheets, hot cast iron, automotive parts, brass fixtures. *Pittsburgh Plate Glass, Brush Div.*

1107. Metal Cleaners
Bulletin B-8 gives tabular data on 15 metal cleaners. *Apothecaries Hall*

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Catalog on detector for any kind of metal or alloy. *RCA*

1109. Metal Sorting
Data on nondestructive sorting tool for raw, semi-finished or finished parts. *Dice*

1110. Microhardness Tester
Bulletin describes the Kentron microhardness tester. *Kent Cliff Laboratories*

1111. Moisture Control
Bulletins 112 and 122 on controlled humidity method. *Niagara Blower*

1112. Moly-Sulphide Lubricant
40-page booklet on Moly-sulphide lubricant gives case histories for 154 different uses. *Climax Molybdenum*

1113. Nickel Alloys
40-page book gives corrosion, physical and mechanical properties of Hastelloy alloys; 13 pages of fabrication data. *Haynes Stellite*

1114. Nickel Alloys
38-page handbook on wire, rod, strip of Monel, Inconel, nickel and nickel clad copper. *Alloy Metal Wire Co.*

1115. Nondestructive Testing
8-page bulletin on equipment for nondestructive testing of bars, rods, tubing. *Magnetic Analysis*

1116. Nonferrous Tubing
Bulletin on seamless, brazed and lockseam tubing in brass and copper. *H & H Tube and Mfg.*

1117. Nuclear Radiation Cell
Data on industrial instrumentation applications of the Ohmart cell, the radioactive sensitive element which converts nuclear radiation into electrical energy. *Minneapolis-Honeywell*

1118. Oil Quenching
8-page brochure tells in detail how carbon steel often can replace alloy steel when additive is used in the quenching oil. *Aldridge Industrial Oils*

1119. Openhearths
Brochure on modern openhearth design and construction. *Loftus*

1120. Phase Contrast
16-page Bulletin D-104 on theory, applications and equipment for phase contrast microscopy. *Bausch & Lomb*

1121. Pickling Baskets
Data on baskets for degreasing, pickling, anodizing and plating. *Jelliff*

1122. Pickling Baskets
12-page bulletin on mechanical picklers, crates, baskets, chain and accessories. *Youngstown Welding & Eng'g*

1123. Plating
8-page booklet on plating rack designed to make spline section or body of rack a permanent tool. *National Rack*

1124. Plating on Aluminum
Recent developments, factors affecting plating techniques, recommended procedures, in "Technical Advisor" No. 23. *Reynolds Metals*

1125. Potentiometers
Article gives technical data on semi-precision potentiometers. *Rubicon*

1126. Precision Casting
Bulletin on mechanically-operated induction furnace for precision casting. *Ajax Electrothermic*

1127. Precision Casting
8-page bulletin on investment castings of various ferrous and nonferrous alloys. *Engineered Precision Casting*

1128. Precision Casting
Discussion of alloy selection and design of investment castings. *Arwood Precision Casting*

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50-page booklet describes protective coatings on a general basis. *Atlas Mineral Products*

1130. Proving Rings
Bulletin on models of proving rings for calibrating Brinell and universal testing machines. *Steel City Testing*

1131. Pure Metals
Data sheets on vacuum melted cobalt, copper, iron and nickel. *Vacuum Metals*

1132. Pyrometer Supplies
56-page Users' Manual and Buyers' Guide. Specifications, prices, thermocouple calibration data. *Bristol Co.*

1133. Pyrometers
New 24-page thermocouple and accessory bulletin. *West Instrument*

(Continued on p. 36A)

(Continued from page 35)

1134. Quenching
"Handbook on Quenching" gives complete information. *E. F. Houghton*

1135. Quenching Oil
8-page booklet on applications and cost reductions in oil-quenching installations. *Sun Oil*

1136. Radiation Pyrometer
Catalog No. 100 tells of direct reading tool for spot temperatures. *Pyrometer Instrument*

1137. Radiography
28-page booklet on products for industrial radiography gives exposure and processing data for various films used. *DuPont*

1138. Radiography
Booklet on quality control through X-ray inspection. *Industrial X-Ray*

1139. Rare Earths
8-page Progress Report Number 1, "Rare Earths in Iron and Steel Melting". *Molybdenum Corp.*

1140. Refractories
16-page book on mullite-base refractories—ramming mixes, mortars, patches, castables. *Mullite Refractories*

1141. Refractories
12-page brochure on products for casting special refractory shapes and for gunning and troweling applications, for services to 3000° F. *Johns-Manville*

1142. Refractories
20-page booklet gives technical information on super refractories. *Refractories Div., Carborundum Co.*

1143. Rhodium Plating
Rhodium plating as replacement for usual plating metals. *Baker & Co.*

1144. Rust Preventives
12-page bulletin on water-soluble rust-preventive. *Production Specialties*

1145. Rust-Proofing
Literature on rust-proofing ferrous metal parts. *American Chemical Paint*

1146. Salt Bath Furnaces
Data on salt bath furnaces for batch and conveyorized work. *Upton*

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75-page manual on salt baths for case hardening and heat treating. *DuPont*

1148. Sand Control
32-page book on defects and troubles in foundry and how to remedy through sand control. *Claud S. Gordon Co.*

1149. Saws
Catalog C-53 describes 35 models of metal-cutting saws. *Armstrong-Blum*

1150. Selective Hardening
Folder on pack-hardening and isolating pastes for selective and rapid case hardening. *Denfis Chemical Labs.*

1151. Shot and Grit
Handy calculator has size data for SAE grades of shot and grit. *Pangborn*

1152. Shot Peening
16-page booklet on selection and use of shot and grit for peening. *Cleveland Metal Abrasive*

1153. Shotblasting
16-page "Primer on the Use of Shot and Grit". Problems of blast cleaning operations. *Hickman, Williams*

1154. Sodium
24-page book on handling sodium in the laboratory and plant. Application to descaling. *Ethyl Corp.*

1155. Solder
Data on cored solder which may be used on stainless steel and nickel alloys. *Alpha Metals*

1156. Spark Testing
20-page spark test guide features spark diagrams of 13 standard tool and die steels. *Carpenter Steel*

1157. Stainless Castings
8-page bulletin gives recommendation charts for type of stainless to use in various corrosive solutions, under various conditions. *Waukesha Foundry*

1158. Stainless Steel
Slide chart. Set top at a certain fabricating operation, bottom shows rating of each standard grade. On reverse side, heat treating and corrosion data are given. *Carpenter Steel*

1159. Stainless Steel
Selector gives machinability, physical and mechanical properties, corrosion resistance of various grades of stainless steel. *Crucible Steel*

1160. Stainless Steel
32-page book on corrosion resistance of stainless steels. 18 tables on tests in acid, neutral and alkaline solutions. *International Nickel*

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Bulletin gives examples of five t
stainless steel castings. *Sivyer*

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36-page booklet on uses of s
steel in the paper industry. *Al*
Ludlum

1163. Steel Tubing
48-page Handbook F-3 on fab
and forging steel tubing. Bending,
cutting and joining operations de
Ohio Seamless Tube

1164. Stress Rupture
Data Card 153 gives stress-ruptu
for nine grades of stainless. *Bab*
Wilcox

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Bulletin on sub-Arctic industri
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Webber Appliance

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tool steel and increase in tool
sulting. *Sub-Zero Products*

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Eclipse Fuel Eng.

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Data on automatic system fo
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e illustrated catalog lists over 130 and measuring equipments for y and production-line use. *Gen- tric*

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e catalog on hydraulic testing s. 10 models described; also ac- . *Riehle*

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e Bulletin TC-9 on thermocouples, detectors, resistance bulbs, ac- . *Wheelco*

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n 6169 on graphite thermocouple arts. *National Carbon*

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e Bulletin 235-4 describes various thermocouples, extension wire er accessories. *Foxboro*

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e data book on properties of com- y pure and alloy titanium, melting, and rolling. 16 charts and micros; ss conversion curves for titanium. *Steel*

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Tool Heat Treating
ation on "Sure-Wear" process for eating high-speed cutting tools. *Treating Co.*

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on high carbon, high vanadium base high speed steel. *Latrobe*

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ties and treatment of general- air-hardening chromium-molyb- ool steel. *Bethlehem*

1187. Tool Steel Failures
124-page book, "Tool Steel Trouble Shooter", analyzes 107 tool failures and assigns causes as among tool design faults, tool steel faults, improper heat treatment, mechanical and operational factors. *Bethlehem Steel*

1188. Tool Steel Heat Treat
Bulletin 1147EE on electric furnace for heat treatment of high speed tool steel. *Hevi Duty*

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Twist the dial of the 9-in. circular selector and read off the tool steel for your application. *Crucible Steel*

1190. Tool Steels
Full information on uses, compositions and heat treatment of carbon and carbon-vanadium tool steels. *Vanadium-Alloys Steel Co.*

1191. Tubing
Bulletin 32 on analyses available, production limits, commercial tolerances, temper designations of seamless and weldrawn tubing. *Superior Tube*

1192. Tungsten Carbide
72-page catalog on tungsten carbide products, including tools, dies, gages, rolls. *Metal Carbides Corp.*

1193. Ultra Strength Steel
Results of three year research and test program evaluating properties of Type 4340 steel for aircraft structures. *International Nickel*

1194. Ultrasonic Cleaning
Folder on Sonogen ultrasonic generator for metal cleaning. *Branson*

1195. Ultrasonic Inspection
Set of application sheets, each describing a specific use for ultrasonic inspection. *Sperry Products*

1196. Vacuum Metallizing
Reprint "High Vacuum Metallizing of Metals and Plastics". *Consolidated Vacuum Corp.*

1197. Welding
3 bulletins on recently developed Fillerarc consumable-electrode gas-shielded welding process. *General Electric*

1198. Welding Alloy Steel
44-page Data Book 4D covers all types of welding of nickel alloy steels. *International Nickel*

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Catalog on Cadweld process and arc-welding accessories. *Erico Products*

1200. Welding Magnesium
Article on inert-gas-shielded metal-arc welding of magnesium includes numerous illustrations and tables of data. *Dow Chemical*

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Various welding processes for magnesium, stress relief and recommend procedures. *Brooks & Perkins*

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Reprint describes procedures for welding stainless, stainless-clad and copper alloy pressure vessels and refinery components. *Air Reduction*

1203. Welding Rods
6-page bulletin on bronze welding rods. Table gives ASTM, AWS and Government specifications. *Titan Metal*

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Bulletin on inert gas-shielded spot welding gun which welds from one side only and without a back-up plate. *Air Reduction*

1205. Wire Baskets
84-page book on fabricated baskets for dipping and heat treating. *Cambridge Wire Cloth*

1206. Wire Tester
Bulletin on automatic wire and cable tester which tests five different sizes at one time. *Riehle*

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Bulletin 8A-3505 on film or direct recording X-ray diffraction apparatus. *X-Ray Div., General Electric*

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248-page catalog and supplement on materials used in X-ray inspection. *Picker X-Ray*

1209. Zinc and Cadmium Plate
Technical data sheets on use of Lusteron salts for zinc and cadmium plating. *Chemical Corp.*

1210. Zirconia
Folder on new, patented process in which each zirconia crystal is stabilized. Characteristics of stabilized zirconia. *Zirconium Corp. of America*

1211. Zirconium
26-page booklet gives physical, mechanical and chemical properties, present and potential uses, supply and prices of zirconium. *Zirconium Metals*

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There are many possible combinations of mechanical, physical and economic characteristics involved in the choice of mechanical tubing. For a particular application, however, there generally is only one combination that is best for your method of manufacturing. *Mr. Tubes can help you obtain that desired combination.*

B&W produces seamless and welded mechanical tubing in a wide range of sizes in carbon, alloy and stainless steels. In addition, B&W mechanical tubing may be obtained in a selection of surface finishes and mechanical properties. Thus, through Mr. Tubes you can obtain tubing to meet your design and fabricating requirements. Mr. Tubes also can help you to produce your product more economically through the saving of time and materials by eliminating rejections and avoiding fabricating problems.

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TB-340 *A guide to the use of seamless mechanical tubing.*

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B&W SEAMLESS and WELDED TUBES

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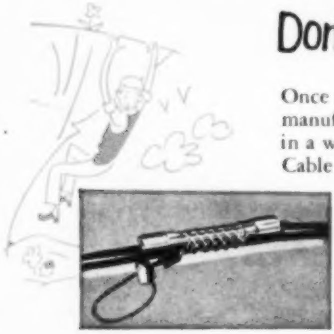
ANACONDA METALS AT WORK

Meet the educated screw

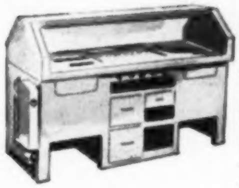
This is a whole family of screws, known as Screwsticks, and joined head-to-toe. Insert a Screwstick in the driver, aim it at the hole—and from there on the Screwstick tightens itself to the predetermined torque, shears itself and gets its head burnished by the following screw which automatically advances itself. It's so fast that American Screw Co. of Willimantic, Conn., which uses ANACONDA Hexagon Brass Rod, refers to it as "jet propulsion".

Don't lose your grip



Once a novelty trick developed by the Chinese, the manufacture of these grips is now an industry. Made in a wide variety of styles and sizes by Economy Cable Grip Co. of Norwalk, Conn., they are used to anchor suspended electric power cables and to seize the end for pulling through ducts. The harder you pull, the tighter they grip. Needless to say, the ANACONDA Bronze Cable, Everdur* Rod and Copper Tube used in their manufacture never weaken from rust.

A fast delivery...with mustard



When baseball fans want their hot dogs, they want them fast—so Stainless Alloy Fabricators of Detroit built this "Double-Header" baseball park hot dog server. Its big capacity for hot dogs—and fast service—is its double bun warmer, one at each end, heated by copper water boilers. If the water runs dry, it's no strike-out. Boilers are made of phosphorized copper sheet with joints formed by fusing the edges with a Heliarc torch. No solder used, no seams to burn open.

How to treat a fracture

A fracture often means long uselessness—but that needn't be true of machinery. Usually braze welding can make it good as new and at a fraction of the time and cost of replacing it. This fractured cast iron conveyor drive sprocket, for example, would have taken two months to replace. The Universal Welding Co., Rochester, N. Y., repaired it in only 7 hours by braze-welding with ANACONDA-997 (Low Fuming) Bronze Welding Rod. Moral: don't count the patient out before consulting your welder.

There's more to this than meets the eye

In our Technical Department you will find a range of experience that covers the entire field of copper and copper-alloy applications in the metalworking industries. If you have a problem of metal selection, we are at your service. *The American Brass Company, Waterbury 20, Connecticut. In Canada: Anaconda American Brass Ltd., New Toronto, Ont.* *Reg. U. S. Pat. Off. 5391

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TEST THESE
Corrosion-Resistant Alloys

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how economical they are

The only way you can be sure that a corrosion-resistant material will work in your plant is to test it under actual operating conditions. Laboratory tests will give you some idea of what to expect, but they don't show the effects of the variables involved in production operations. That is why we have prepared standard test specimens of HASTELLOY nickel-base alloys . . . and they are available to you without cost.

Test these alloys yourself against the materials you are now using, or against others that you are considering using. Prove to yourself that they have exceptional corrosion resistance . . . high mechanical strength, even at elevated temperatures . . . and that they are economical to use. We can support these claims with records of laboratory tests and with case histories of actual installations in chemical, petroleum, textile, and metalworking plants over the past 20 years. But don't take our word for it—see for yourself.

Use the handy coupon below to order your samples of HASTELLOY alloys. Alloys B, C, and F are available in either cast or wrought forms, while alloy D is supplied as castings only. If the equipment you have in mind is to contain welded joints, be sure to advise us, so that we may furnish you with welded samples.

"Haynes" and "Hastelloy" are registered trade-marks of Union Carbide and Carbon Corporation.

These standard spool-type test specimens of HASTELLOY alloys are available on request.

HAYNES Trade-Mark *alloys*

Haynes Stellite Company
A Division of
Union Carbide and Carbon Corporation
UCC

USE THIS HANDY COUPON

Haynes Stellite Company, UCC, 731 S. Lindsay St., Kokomo, Ind.
Please send me, without obligation, the following samples of HASTELLOY alloys: (Please Check)

CAST: ☐ B ☐ C ☐ D ☐ F
WROUGHT: ☐ B ☐ C ☐ F

☐ Above samples should have welded joints.

NAME ____________
COMPANY ____________
ADDRESS ____________

No. 123 of a Series of Typical Installations

Sunbeam STEWART

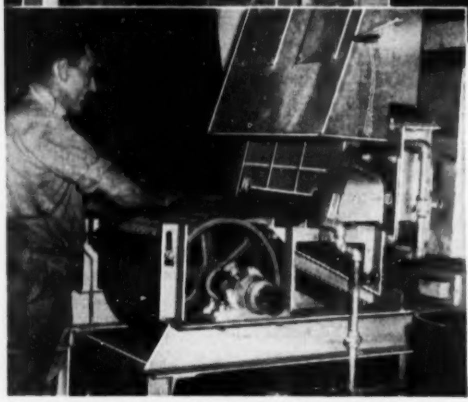
THE BEST INDUSTRIAL FURNACES MADE

HOW SUNBEAM FURNACES HELP MANUFACTURERS REDUCE COSTS AND KEEP THEMSELVES COMPETITIVE

ANNEALING GASKETS AND MISCELLANEOUS PARTS

At JOHNS-MANVILLE PRODUCTS CORP.—Goetze Branch, New Brunswick, N. J.

Charge and side view of the Sunbeam Stewart annealing furnace at Johns-Manville. Being gas-fired, this furnace employs a comparatively low cost fuel with good heating characteristics, fast start-up and good flexibility. Extreme flexibility in operating characteristics allows them to utilize this furnace to process ferrous and non-ferrous alloys.



Workman charging the Sunbeam Stewart atmosphere controlled, gas-fired annealing furnace. Full protection against oxidation is provided during both heating and cooling cycles. Temperatures between 800° and 1600° F. can be employed for the various materials.

Based upon their experience with a previously installed Sunbeam Stewart atmosphere-controlled annealing furnace, Johns-Manville added a second identical unit to provide the necessary capacity for increased production requirements. Material handled at Johns-Manville consists of lightweight copper requiring low temperatures, as well as heavy ferrous metal nozzle rings requiring higher temperatures and longer heating cycles. An exothermic cracked gas atmosphere protects work during heat treatment. One generator, located between the furnaces, supplies sufficient atmosphere. It has adequate volume to provide a continuous purging action for both sets of heating and cooling chambers. Each furnace has a maximum capacity of approximately 350 pounds of work per hour, subject to temperatures and materials in process. Sunbeam Stewart full muffle design is ideally suited for atmosphere controlled annealing of both ferrous and non-ferrous material. Products of combustion completely envelope the muffle. The bottom of the muffle is heated partially by radiation from the ceramic hearth. This type of design assures even heating over the entire temperature range of 800° to 1600° F.

For all practical purposes these furnaces are completely automatic and all that is required in their operation is the manual or automatic loading of the conveyor belts. They are suitable for practically all controlled atmosphere annealing where clean results are desired. Other atmospheres, such as endothermic cracked gas, dissociated ammonia, etc., can be adapted for use in this Sunbeam Stewart installation.

MODERN AUTOMATIC HEAT TREAT EQUIPMENT MAY BE THE ANSWER TO YOUR PROBLEM

Sunbeam engineers can help you keep pace with modern production methods. Replacement of obsolete or inefficient heat treating equipment with an automatic Sunbeam installation reduces costs, improves quality, pays for itself in a short time.

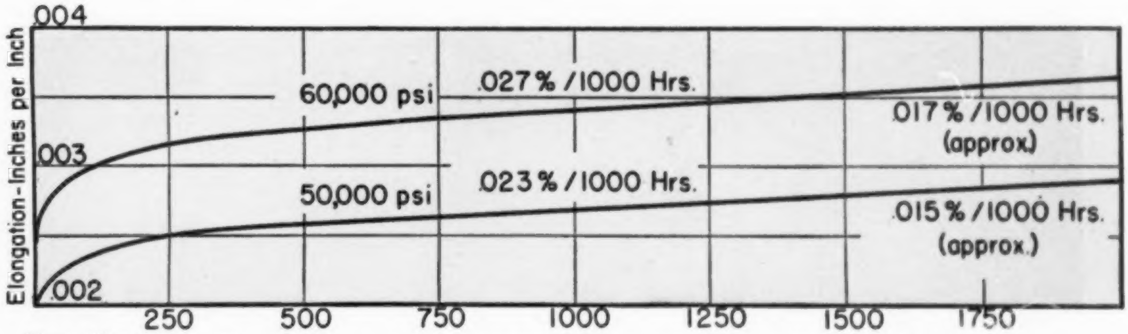
Sunbeam CORPORATION (Industrial Furnace Division)

Main Office: Dept. 108, 4433 W. Ogden Ave., Chicago 23—New York Office: 322 W. 48th St., New York 19—Detroit Office: 3049 E. Grand Blvd., Detroit 2
Canada Factory: 321 Weston Rd., Toronto 9

A letter, wire or 'phone call will promptly bring you information and details on SUNBEAM industrial furnaces, either units for which plans are now ready or units especially designed to meet your needs. Or, if you prefer, a SUNBEAM engineer will be glad to call and discuss your heat treating problems with you.

SAVE ALLOYS, GET HIGH ALLOY PERFORMANCE IN GAS TURBINES WITH "17-22-A" (S) STEEL

Contains less than 3% alloy
Gives maximum creep resistance to 1000°F.



Time-elongation creep curves at 900°F. show high creep resistance of "17-22-A" (S)

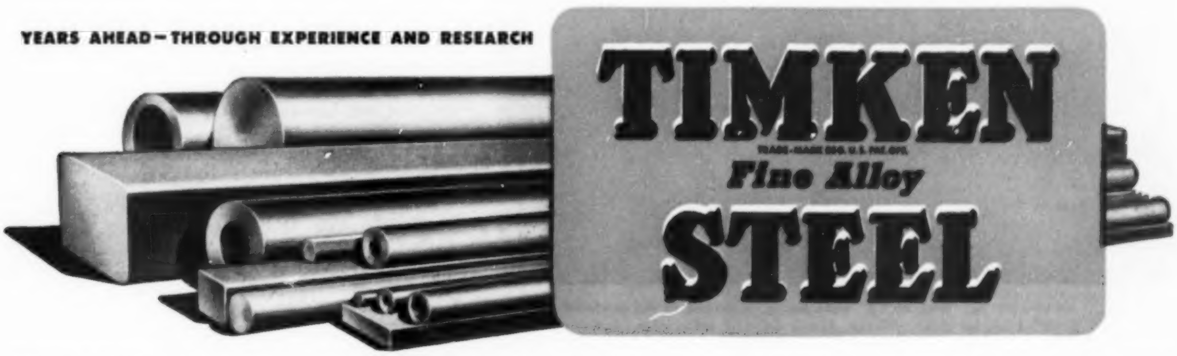
If your gas turbine parts operate at temperatures not exceeding 1000°F., you can save critical alloys, yet get high alloy performance by using "17-22-A"(S) steel produced by the Timken Company.

"17-22-A"(S) steel contains less than 3% alloy. It permits you to cut costs. Developed by metallurgists of the Timken Company, "17-22-A"(S) has been used successfully for 10 years in refinery and steam power applications. The graph above shows its creep resistance at 900°F.

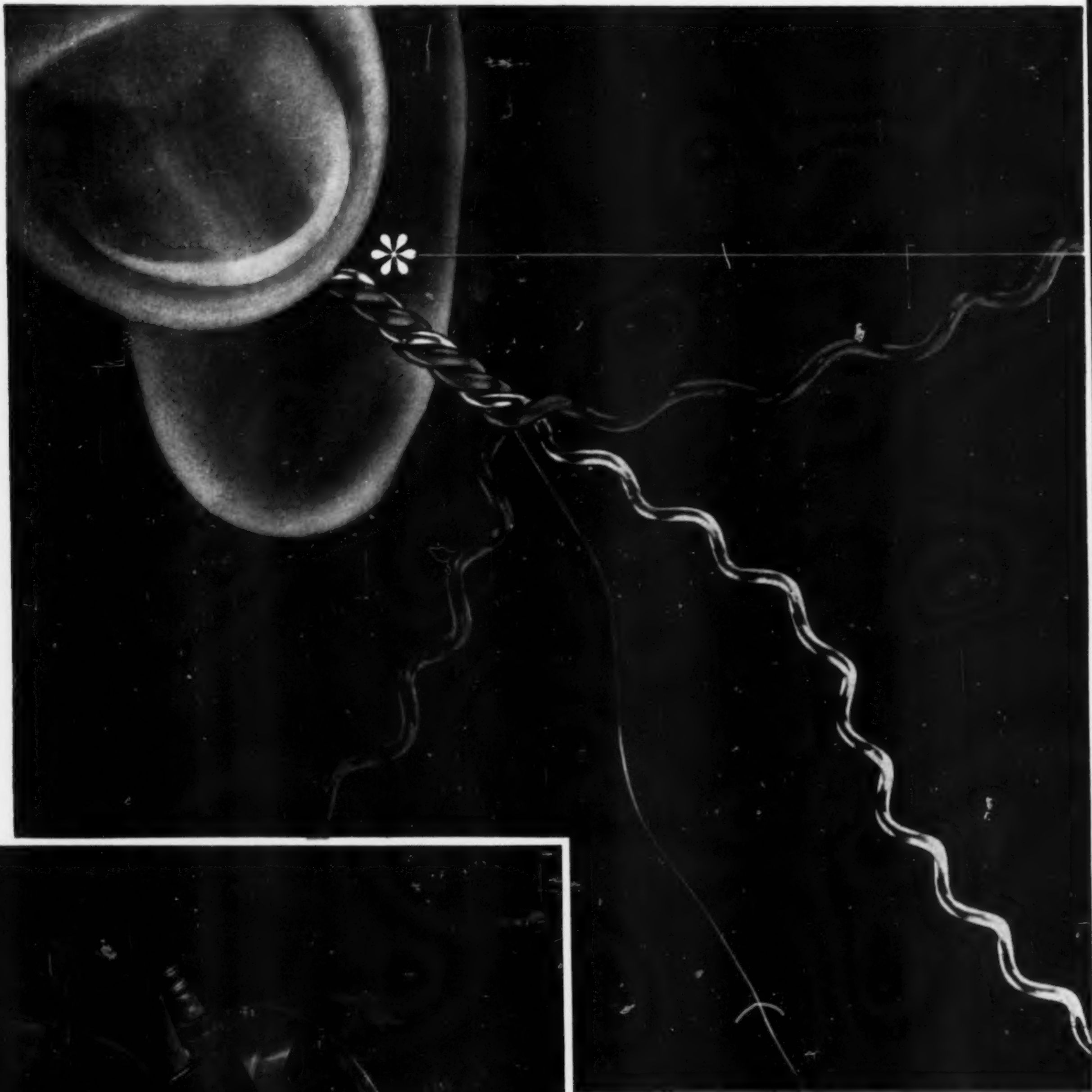
"17-22-A"(S) also resists heat checking and thermal cracking. It is readily workable up to 2300°F. It's easy to machine and weld. Maximum high temperature properties can be developed by normalizing and tempering, minimizing the possibility of distortion and quench cracking.

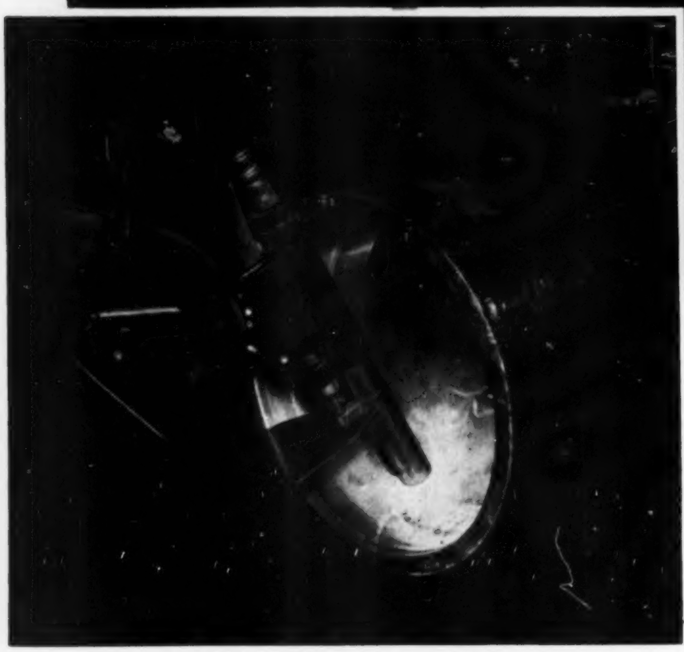
For complete information on "17-22-A"(S), and its companion analysis, "17-22-A"(V)—used at temperatures up to 1100°F.—write for Technical Bulletin Number 36A. And for help with your high temperature problem, call upon our Technical Staff. The Timken Roller Bearing Company, Steel and Tube Division, Canton 6, Ohio. Cable address: "TIMROSCO".

YEARS AHEAD—THROUGH EXPERIENCE AND RESEARCH



SPECIALISTS IN FINE ALLOY STEELS, GRAPHITIC TOOL STEELS AND SEAMLESS TUBING





The problem of depositing special alloys that are hard to draw and spool for use with the Aircomatic process is neatly answered by the use of stranded wire, an Airco development. In the wire used for these aluminum-bronze overlays, two strands of copper and one of aluminum are wound around a fine iron core. Melted by the arc, the component metals mix and alloy themselves into aluminum bronze of the correct analysis.

AIRCO

An overlay ⅛" thick and 2" wide being deposited in the confined area of a 10"-diameter steel cylinder. Actual welding takes about twenty minutes.

Close-up of the finished aluminum-bronze overlay before machining. Note the smooth beads and the absence of spatter.

After machining, the overlay looks like this. Aircomatic's concentrated heat input produces excellent fusion.

"TAM"* FUSED SALT (Potassium Zirconium Tetrachloride) is used in large quantities in extruded magnesium alloys and in casting alloys free from rare earth additions.

"TAM"* also offers a new ***Master Zirconium*** Alloy containing approximately 32% Zirconium for use in magnesium castings containing rare earth additions.

Write to us at our New York City address for details.

*TAM is a registered trademark.

TAM PRODUCTS
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TITANIUM ALLOY MFG. DIVISION
NATIONAL LEAD COMPANY

Executive and Sales Offices: 111 BROADWAY, NEW YORK CITY
General Offices, Works and Research Laboratories: NIAGARA FALLS, N. Y

ship or store machinery?

Here's important news

Gulf Oilcoat T

prevents rust in lubricating systems
but does not contaminate lubricating oils

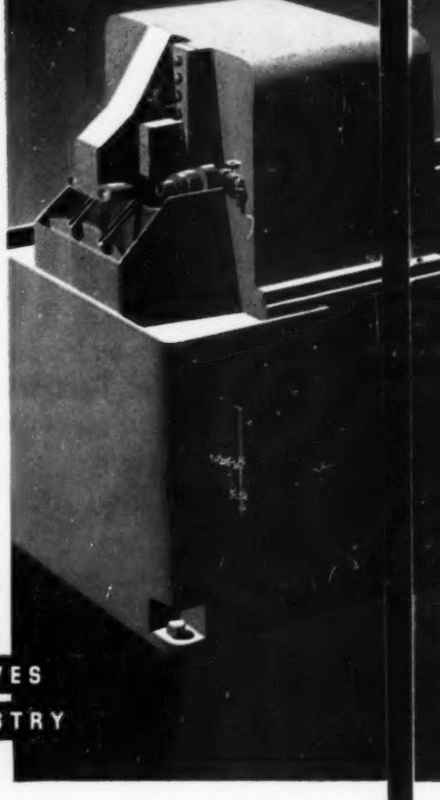
The compatibility of Gulf Oilcoat T with lubricating oils is of particular importance to you if the lubricating systems of your new machines are flushed with the same oil that is to be used for lubrication.

The use of a rust preventive that is not compatible may result in the development of harmful precipitates in the lubricating oil and considerably shorten its period of usefulness. Oils so contaminated may even cause machine parts to be damaged, thus increasing maintenance costs.

Several large machinery manufacturers have thoroughly tested Gulf Oilcoat T. They now use it extensively to protect the vital lubricating systems of their equipment against rust during shipment and installation.

Because of its light viscosity, Gulf Oilcoat T may be applied by spray, brush, dipping, or circulation.

If you manufacture, ship, store, or seasonally shut down machinery that has a lubricating system, ask a Gulf Sales Engineer to explain in more detail the advantages of Gulf Oilcoat T. Contact your nearest Gulf office now, or send the coupon below.



GULF OIL CORPORATION · GULF REFINING COMPANY
1822 GULF BUILDING, PITTSBURGH 30, PA. MP

Please send me, without obligation, a copy of your pamphlet on Gulf Oilcoat T.

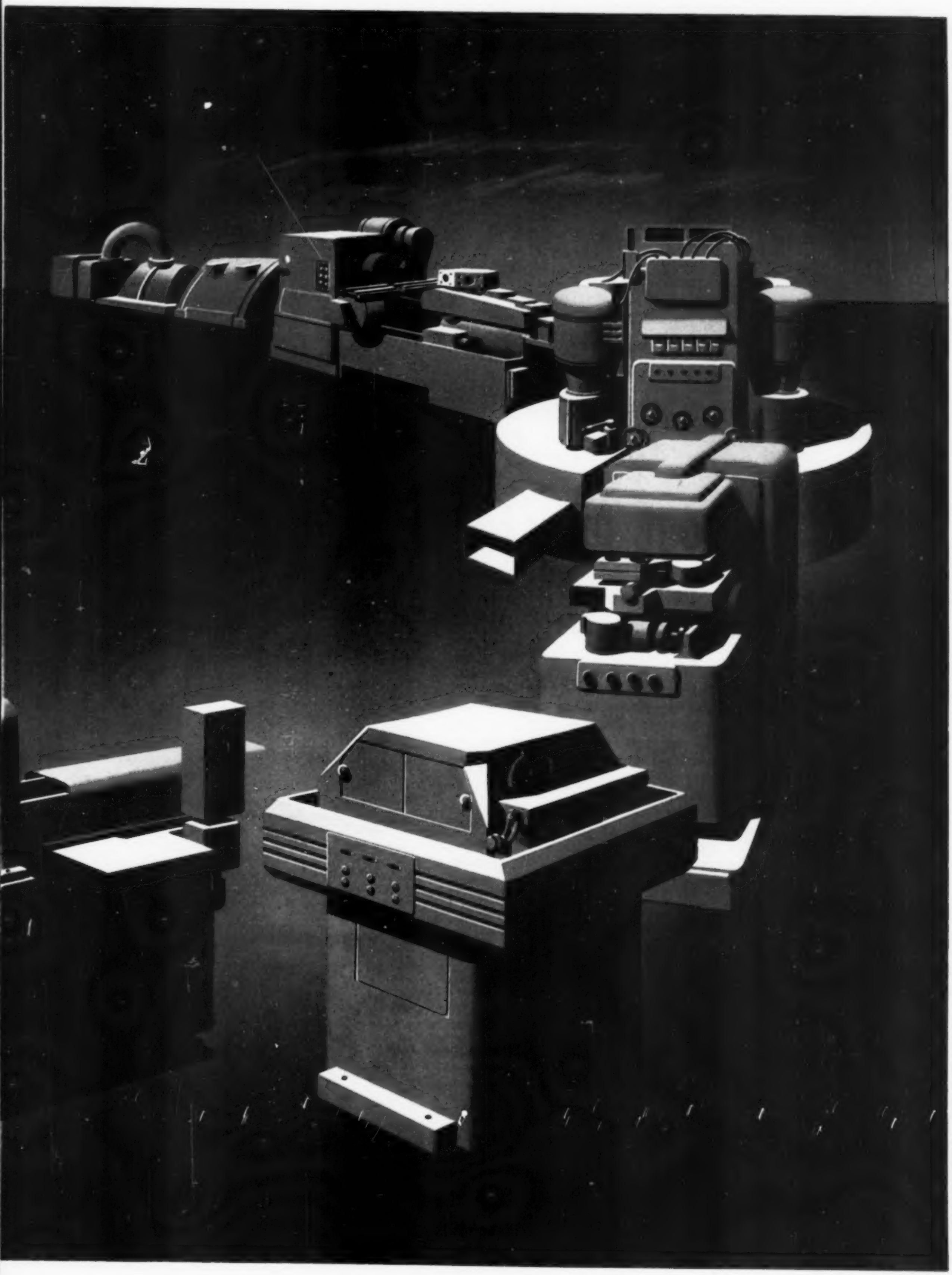
Name....................

Company....................

Title....................

Address....................

GULF SERVES INDUSTRY



There's a HOUGHTO-QUENCH to fit your "S" Curve needs

SPEED... The fastest quench this side of water — if you need it. Or a slower speed oil, if that is required.

SURETY... Uniform quenching results, heat after heat, month after month.

STABILITY... No breakdown, no sludge, no light ends to "crack off," for Houghto-Quench is fortified for stability and long life.

Ask your Houghton Man or write
E. F. Houghton & Co., 303 W. Lehigh Avenue
Philadelphia 33, Pa.

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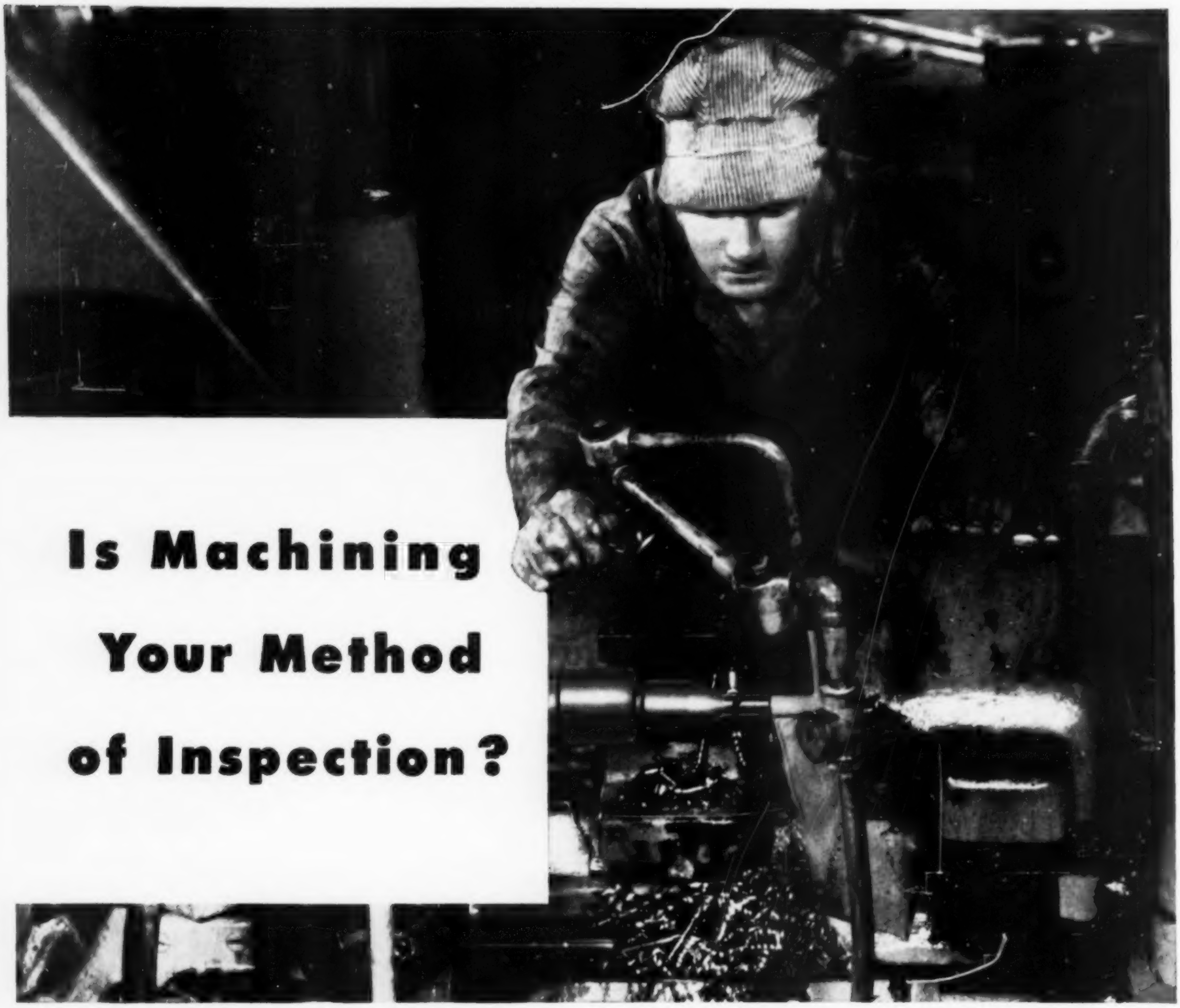
E. F. HOUGHTON & CO.
PHILADELPHIA · CHICAGO · DETROIT · SAN FRANCISCO

Ready to give you on-the-job service . . .


the elements lose...
and beauty wins
with storm-and-screen doors of
SUPERIOR Type 430
STAINLESS strip steel
Lustrous, handsome, unaffected by exposure the year around, stainless steel storm-and-screen doors are the home-owner's perennial joy. ● Built of Superior Type 430 Stainless Strip, these popular doors are the fabricator's delight as well, because our steel is made right, checked right, easy-handling at every step. Can we serve you?
Superior Steel
CORPORATION
CARNEGIE, PENNSYLVANIA



Is Machining Your Method of Inspection?

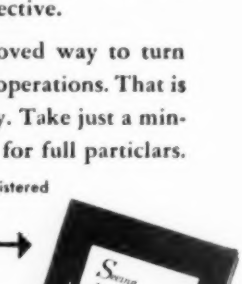
IF YOU depend on machining to locate hidden defects in parts or material, you pay an exhorbitant price for "inspection"—through wasted labor and machine time. Further, there may be defects "getting by" that can later cost someone plenty in trouble and dollars.

Machining defective materials is a dead loss! Inspection with *Magnaflux is the modern, economical way that locates defects *before* machining. It is fast, non-destructive and *accurate.* If there is a defect Magnaflux locates it—positively, clearly and unmistakably, whether it is a surface or subsurface crack, a forging lap, a tear, or what have you? Inspection on an engineered Magnaflux unit proves cheaper than even visual inspection, as well as more effective.

Magnaflux inspection is a proved way to turn wasteful losses into profitable operations. That is mighty important to you today. Take just a minute or two right now to write for full particlars.

*Magnaflux and Magnaglo are U.S. Registered trademarks of Magnaflux Corporation.

What Magnaflux is, and how it saves money, is described in booklet "Seeing Isn't Always Believing." Write for your free copy.



MAGNAFLUX

DETECTS DEFECTS

MAGNAFLUX CORPORATION

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'54 Forecast: More Aluminum Products Than Ever Before

Reynolds
ALUMINUM REPORTER

Modern Design Has Aluminum in Mind

★ ★ ★ Thirteenth in a Series to Industry on Aluminum Uses and Developments ★ ★ ★

NEW SEAL PROGRAM AVAILABLE TO FABRICATORS

Aluminum Pigments Offer Variety of Finishes . . . Add Beauty and Protection

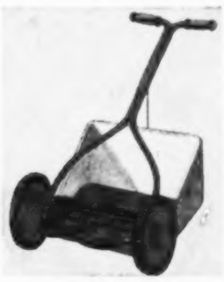
Polychromatic finishes give designers a new flexibility of design. The sparkling flakes of Reynolds "non-leafing" aluminum pigments added to colored lacquers and enamels give products a lasting beauty, depth and iridescence that enhance their appearance. And it doesn't matter whether the product is made of metal, plywood, plastic, composition, or wood—polychromatic finishes beautify and protect any solid surface.

Wrinkled

Reynolds special patented process eliminates the normal leafing characteristic of aluminum pigments. As a polychromatic finish sets up, the aluminum pigment remains evenly dispersed in the lacquer or enamel to catch light beneath the surface, thus providing depth and sparkling beauty as well as a durable, protective surface. This is true of all three types of polychromatic finishes made with Reynolds "non-leafing" aluminum pigments—Regular, Hammered and Wrinkled.

Regular

These fine finishes are perfect for a wide variety of products. Regular for: cars, trucks, gasoline station pumps, etc. Hammered for: lawnmowers, vacuum cleaners, compressor housings, thermos jugs, etc. Wrinkled for: typewriters, business machines, air conditioners, etc.



Hammered

For names of polychromatic finishes manufacturers and a copy of the free brochure, "Industrial Polychromatic Finishes," contact the Reynolds Office listed under "Aluminum" in your classified telephone directory. Or write the Reynolds Metals Company, 2576 South Third Street, Louisville 1, Kentucky.

"Designed in Reynolds Aluminum" Seal Offers Fabricators an Opportunity to Put Powerful Reynolds Advertising and Merchandising Support Behind Their Products

As a means of giving their fabricating customers the added benefits of millions of dollars of advertising and merchandising support, Reynolds Metals Company takes pride in announcing a new, "Designed in Reynolds Aluminum" Seal Program for fabricators who use Reynolds Aluminum in their end products.

Aluminum Screw Machine Stock Gives Three Times the Number of Pieces Per Pound

Reynolds Aluminum screw machine alloys are recognized throughout industry as having exceptionally good machinability. For this reason more and more manufacturers are relying on Reynolds as their source of supply.

Aluminum screw machine stock has many **advantages** . . . it gives three times the number of pieces per pound, it is free-machining, has good formability, is strong and corrosion resistant. Reynolds Aluminum machining alloys are available in both bar and rod.

If you have design or production problems take advantage of Reynolds trained technical staff of aluminum specialists. They will help you get set for fast, economical production. With proper techniques and tooling methods, aluminum machining rates are limited only by the top speed of machine tools.

For prompt service, call the Reynolds Office or your nearby Reynolds Distributor, listed under "Aluminum" in your classified directory.

For the complete story on machining with aluminum send for a copy of "Machining Aluminum Alloys". Free when requested on business letterhead. Write Reynolds Metals Company, 2576 South Third Street, Louisville 1, Ky.

Because customer acceptance and identity is more vital than ever today in the "battle of the brands" the addition of the Reynolds trademark to the manufacturer's trademark offers a real chance for "Double Identity"—double impact at the consumer level at no additional cost to manufacturers who use Reynolds Aluminum.

Designed in REYNOLDS ALUMINUM

This new "Designed in Reynolds Aluminum" Seal will be heavily promoted to millions of consumers through the popular "Mister Peepers" show Sundays on NBC TV.

National magazine advertising will reach millions more with ads telling customers to look for this new Reynolds Seal on the products they buy. Farm radio shows in 46 selected markets will also promote it. Extensive trade promotions and advertising to business leaders will also be made.

It all adds up to millions of dollars in Reynolds promotion benefiting Seal users.

Reynolds decision to offer this new program to fabricators was made after a survey of the results of the Reynolds Wrap Seal Program launched in 1953 for the benefit of food manufacturers who use Reynolds Aluminum foil in packaging their products. This program has resulted in sales advantages to participating manufacturers and indications are that this new Reynolds Seal Program for fabricators will be even more successful.

QUALITY PROTECTED WITH REYNOLDS WRAP ALUMINUM PACKAGING

Reynolds Industrial Styling and Design Department will assist manufacturers interested in this new program with design and engineering work on their products. For details on how you and your company can qualify to participate in this great new Seal Program, simply write Reynolds Metals Company, 2576 So. Third St., Louisville 1, Kentucky.

MORE INTERESTING NEWS ABOUT ALUMINUM ON NEXT PAGE

(Continued From Preceding Page)

Aluminum Powder Used in "Cold Solder"

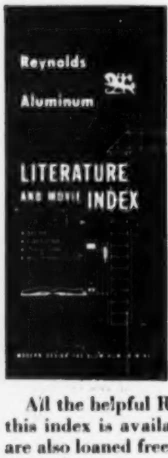
A "cold solder" which provides the perfect coating, a hard setting putty and an excellent filling compound—all wrapped into one—for hundreds of industrial, auto body repair and homecraft uses is now being marketed under many trade names.

This product is excellent for production, maintenance and repairs requiring a coating or filler with the permanence and hardness of non-corrosive metal. It's easy to use. It may be applied with a putty knife, brushed or sprayed on as the particular item dictates. It sets up rapidly and when dry can be worked like metal—drilled, sanded, buffed, etc.

Of the three holes like that at left originally in this specimen, the center one has just been filled in with "cold solder" while the one at the right previously filled in, has now been sandpapered smooth to complete the repair.

Reynolds Aluminum Powder is an important basic ingredient in many brands of this new "cold solder." For a list of manufacturers write Reynolds Metals Company, 2576 South Third Street, Louisville 1, Kentucky.

Complete Index of All Reynolds Industrial Literature and Films Available



More than seventy-five handbooks, brochures, reprints of publication articles and nine films are listed by title, with description, in Reynolds Literature and Movie Index.

This extensive literature and film listing is conveniently grouped under the headings of Design, Fabrication, Application, Product, General and Movies so that you can quickly locate and select the material of particular interest to you.

All the helpful Reynolds literature listed in this index is available without charge. Films are also loaned free. To get your copy of Reynolds Literature and Movie Index, simply write today to Reynolds Metals Company, 2576 South Third Street, Louisville 1, Ky.

Reynolds Aluminum Fabricating Service Offers Facilities for Producing Room Air Conditioner Evaporators and Condensers

Reynolds wide experience in refrigeration, as one of the nation's leading producers of parts for this industry, has pointed up the advantages of aluminum evaporators and condensers in room air conditioners. This experience—plus Reynolds skill, mass production facilities and quality control from mine to finished product—assures production of all-aluminum evaporators and condensers to quality standards exceeding industry requirements.

All-aluminum evaporators and condensers, produced by Reynolds Aluminum Fabricating Service, assure rapid heat transfer—aluminum fins and tubes facilitate fast, economical cooling and efficient operation. All-aluminum evaporators and condensers can't rust, thus there's no danger of rust from these parts causing unsightly stains below the outside of the window. Tubing and fins, both of aluminum, eliminate the possibility of bimetallic action.

Aluminum's light weight aids in portability and ease of installation. Aluminum is strong—gives years of dependable service. And aluminum is economical. These aluminum advantages add up to serviceability, efficiency and economy unmatched by any other material.

Helpful literature available from Reynolds Aluminum Fabricating Service includes brochures on Appliance Parts, General Facilities and Roll Formed Shapes. For your free copy of any or all of these three brochures, simply write Reynolds Aluminum Fabricating Service, 2065 South Ninth Street, Louisville 1, Kentucky.

Lower Costs Possible for Tools, Dies and Fixtures

Tools, dies and fixtures made from Reynolds Aluminum Cast Plate and Bar have high dimensional stability and provide better performance and longer production life than other low cost stock.

The outstanding features of this revolutionary material include fine grain structure; precision machined surfaces; light weight; low cost; fast, free machining; good weldability; excellent thermal characteristics. It is available as plate up to 4" x 48" x 144" and as bar up to 8" x 8" x 144".

For free brochure, "Reynolds Aluminum Cast Plate and Bar for Machine Shops, Foundries and Pattern Shops," write Reynolds Metals Company, 2576 South Third Street, Louisville 1, Kentucky.

New Reynolds Plant Lifts Reduction Capacity to 829 Million Pounds

The new Reynolds Metals Company Robert P. Patterson aluminum reduction plant located in Arkadelphia, Arkansas, is now in operation. This plant, shown below, has an annual rated capacity of 110 million pounds of virgin aluminum giving Reynolds an annual production capacity of 829 million pounds.

Opening of the Robert P. Patterson plant marks another important milestone in Reynolds continued expansion in the aluminum industry. Alumina, which is converted into metallic aluminum at the Patterson plant, is supplied by Reynolds alumina plant at Hurricane Creek, Arkansas and La Quinto plant near Corpus Christi, Texas.

Bauxite for the alumina plants is mined near Bauxite, Arkansas, and at Reynolds extensive, new facilities in Jamaica.

an ACCO product

Wilson "ROCKWELL"* Hardness Testers

NOW...
you can own
the BEST
for only
$550
(less accessories
F.O.B. Bridgeport)

3-JR MODEL

6 Features for Tool Room and Production Testing

This MODEL 3-JR WILSON "ROCKWELL" Hardness Tester is proving invaluable for tool room use and most production testing. It will pay for itself many times over by eliminating costly complaints from your customers.

These features make for unusual accuracy and long life—

1 Totally enclosed dirt and dust-proof "Zerominder" dial gauge.

2 Gripsel clamp screw for quick change and proper seating of penetrator.

3 All controls conveniently grouped.

4 Enclosed, easy-to-reach, variable speed dash pot.

5 Stainless steel elevating screw.

6 Standardized weights.

This machine will test small work as well as the smallest size machine and requires but 12" by 20" of bench space. It has a maximum vertical capacity of 8" and a horizontal reach of from 5¼" to 5½". The height from the bench to center line of the gauge is 24".

Model 3-JR is furnished with 4 standard anvils. If heat-treated and hardened steel is being tested a diamond BRALE penetrator is necessary. This may be purchased at a small additional cost.

The many models of WILSON "ROCKWELL" testers for normal and superficial hardness testing offer the utmost precision for production as well as laboratory work. The various models of WILSON "ROCKWELL" and TUKON micro and macro hardness testers cover most of the entire range of scientific uses.

WILSON hardness testers are available in many styles with accessories for testing flats, rods, rounds and odd shapes. Let us tell you about WILSON TUKON for micro-indentation testing. Write today for literature and prices. *Trade Mark Registered*

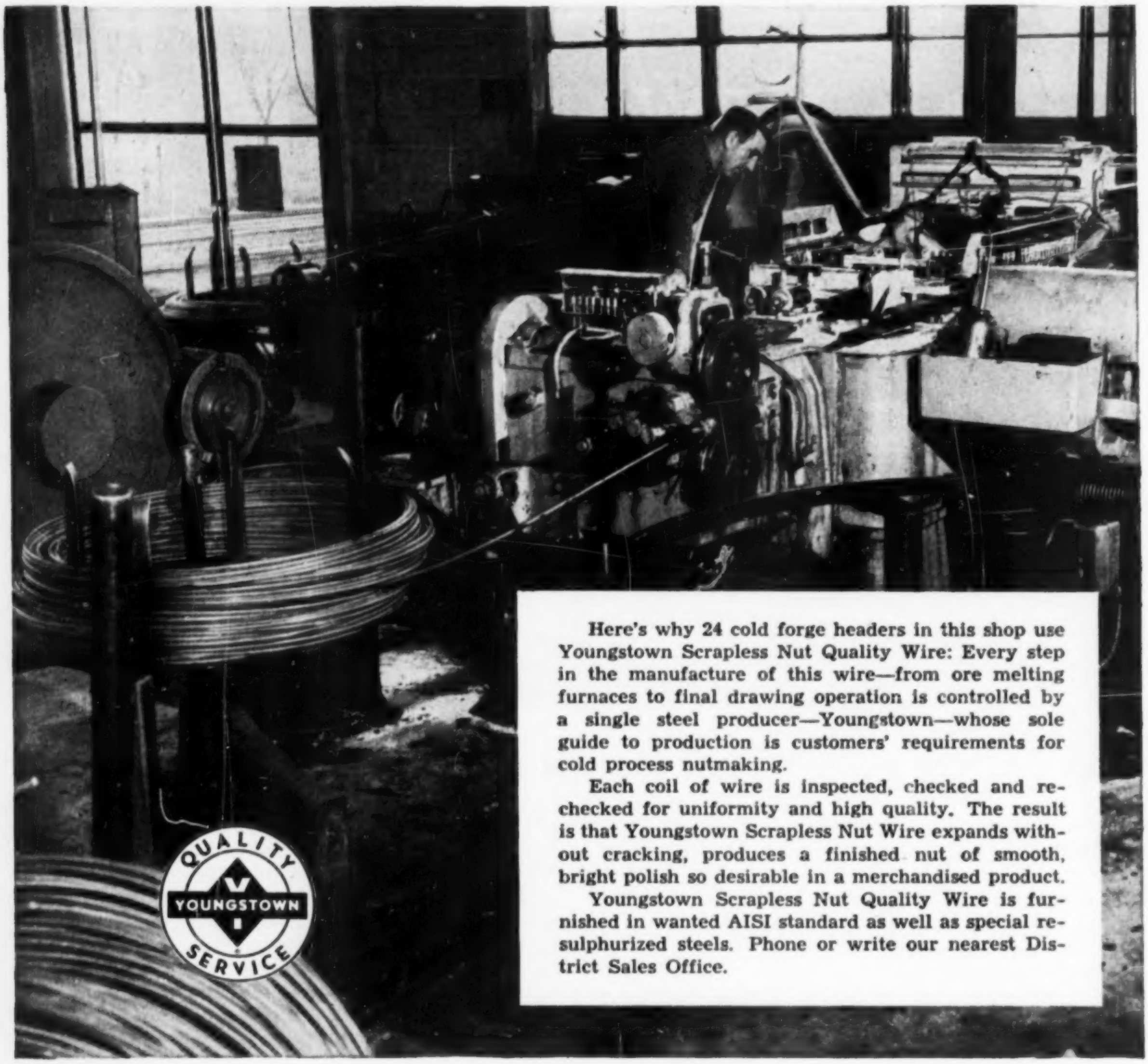
ACCO Wilson Mechanical Instrument Division
AMERICAN CHAIN & CABLE

A C C TRADE MARK

230-F Park Avenue, New York 17, N. Y.

plus BRALES and TUKON

NUTS DON'T CRACK WHEN FORGED FROM YOUNGSTOWN SCRAPLESS NUT WIRE



Here's why 24 cold forge headers in this shop use Youngstown Scrapless Nut Quality Wire: Every step in the manufacture of this wire—from ore melting furnaces to final drawing operation is controlled by a single steel producer—Youngstown—whose sole guide to production is customers' requirements for cold process nutmaking.

Each coil of wire is inspected, checked and rechecked for uniformity and high quality. The result is that Youngstown Scrapless Nut Wire expands without cracking, produces a finished nut of smooth, bright polish so desirable in a merchandised product.

Youngstown Scrapless Nut Quality Wire is furnished in wanted AISI standard as well as special resulphurized steels. Phone or write our nearest District Sales Office.

Youngstown SCRAPLESS NUT QUALITY WIRE

THE YOUNGSTOWN SHEET AND TUBE COMPANY *Manufacturers of Carbon, Alloy and Yoloy Steel*

General Offices: Youngstown, Ohio - Export Office: 500 Fifth Avenue, New York 36, N. Y.

PIPE AND TUBULAR PRODUCTS - CONDUIT - BARS - RODS - COLD FINISHED CARBON AND ALLOY BARS - SHEETS - PLATES - WIRE - ELECTROLYTIC TIN PLATE - COKE TIN PLATE - RAILROAD TRACK SPIKES

How many SPARKS in a Spark Plug?

Surprising, the confidence that people have in spark plugs. No one stops to question how many "sparks" they're good for, because long-life performance has come to be taken for granted. Yet, when you get right down to it, you'll find good reasons for this complete consumer confidence. And, from a "sparking" point of view, perhaps the most important is the almost universal use of special Hoskins alloys for the vital electrode wires.

Producing the wire that sparks your car to power is a tough and tricky business. It requires special care in the selection of raw materials. Special melting and production techniques. Plus extremely close control over alloy composition and uniformity of quality throughout the entire manufacturing process.

Yet that's exactly the kind of alloy that Hoskins is qualified to produce best. For, among the other quality-controlled alloys developed and manufactured by Hoskins are: Alloy 717—for facing engine valves; Alloy 785—for brazing belts; Alloy 502—for countless heat resistant mechanical applications. Then, too, there are the Chromel-Alumel thermocouple alloys . . . guaranteed to register true temperature-EMF values within specified close limits. And, of course, Hoskins CHROMEL . . . the *original* nickel-chromium resistance alloy used as heating elements and cold resistors in countless different products.

Hot stuff for hot jobs! Hoskins Alloy 502 is ideally suited to many mechanical-structural applications.

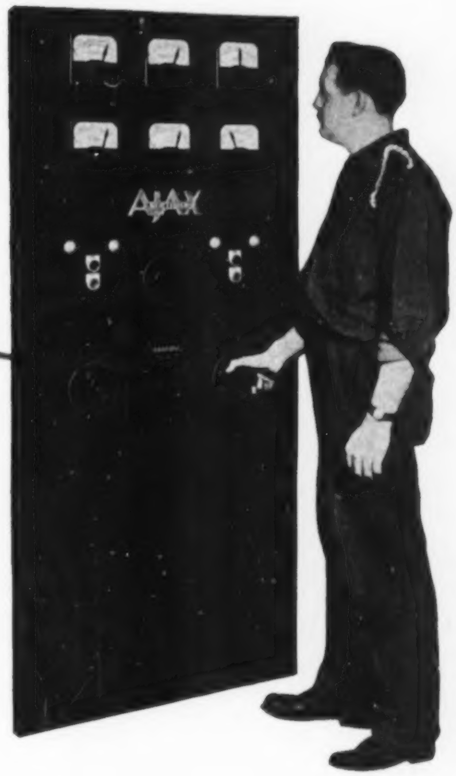
Heating elements made of Hoskins Chromel deliver full-rated power throughout their long and useful life.

Chromel-Alumel thermocouple alloys accurately measure exhaust temperatures of jet aircraft engines.

Chromel
NICKEL CHROMIUM WIRE

HOSKINS
MANUFACTURING COMPANY
4445 LAWTON AVENUE, DETROIT 8, MICHIGAN

COMPLETE CONTROL



makes AJAX-NORTHRUP induction melting...

1. FASTEST
2. MOST PRECISE
3. MOST ECONOMICAL

Consider carefully . . . when an AJAX 50 kw furnace melts steel faster than any other furnace, there must be a difference. There is. Kw for kw, an Ajax-Northrup furnace *always* provides the shortest melting time due to its highly developed, easy-to-operate controls.

The flexibility of Ajax-Northrup controls permits faster melting because power input can be kept at a constantly high value . . . despite changes in electrical characteristics that occur during the melt. This flexibility also means more precision in casting since pouring temperatures can be maintained exactly as desired.

Ajax-Northrup controls incorporate a rotary power factor switch which is a fool-proof interlocked system. Capacitor steps are conveniently added by single units without guesswork. If any unit is removed, the power supply is automatically opened. Power is likewise controlled by a rotary tap switch adding flexibility to furnace operation. Voltage is controlled by a single rheostat which gives the operator full control from near zero to the maximum rating.

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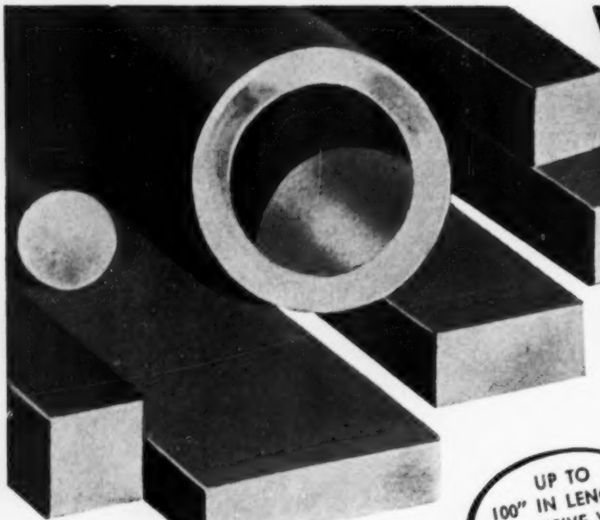

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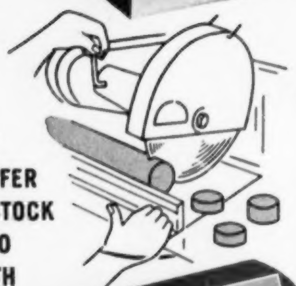

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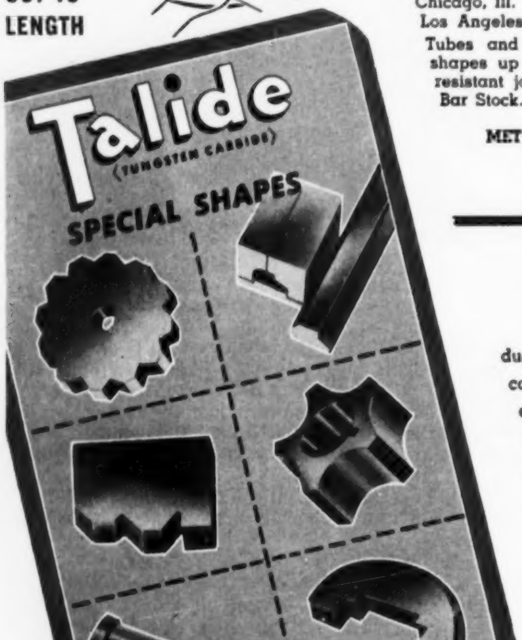

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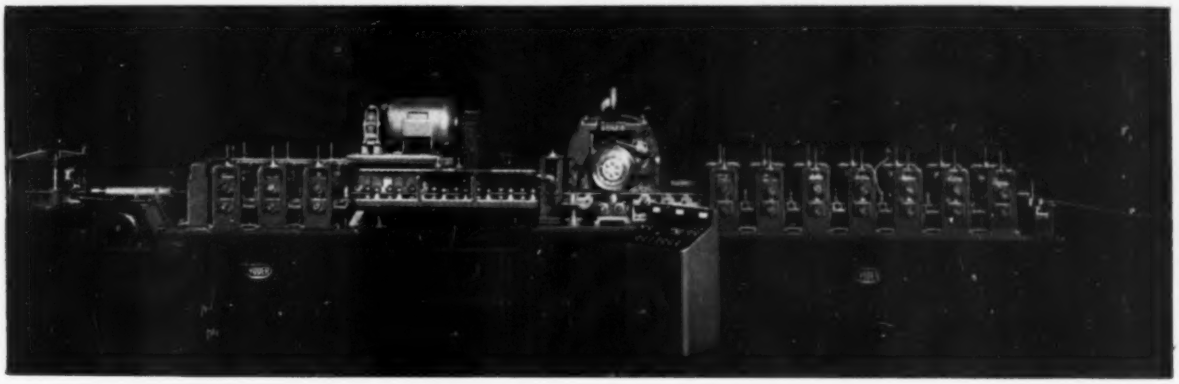

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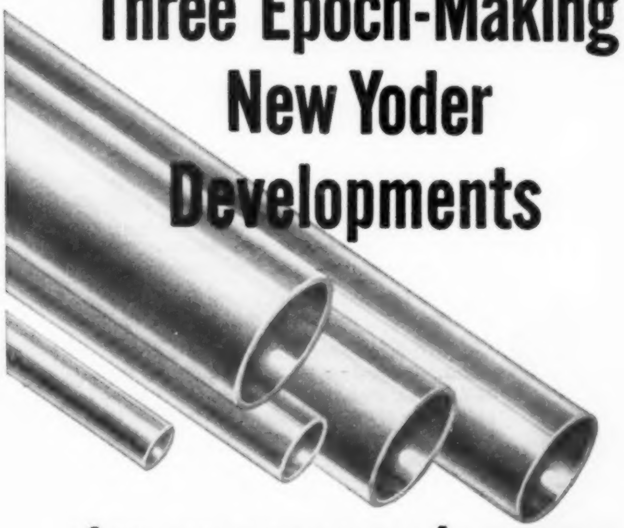

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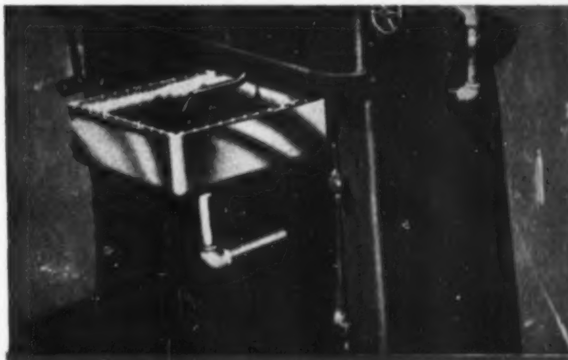
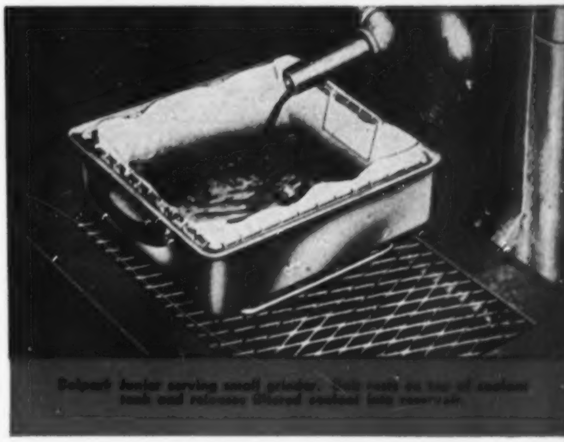


Delpark Junior installation on gear hobber. Coolant flows through tray and returns to machine through lower pipe.



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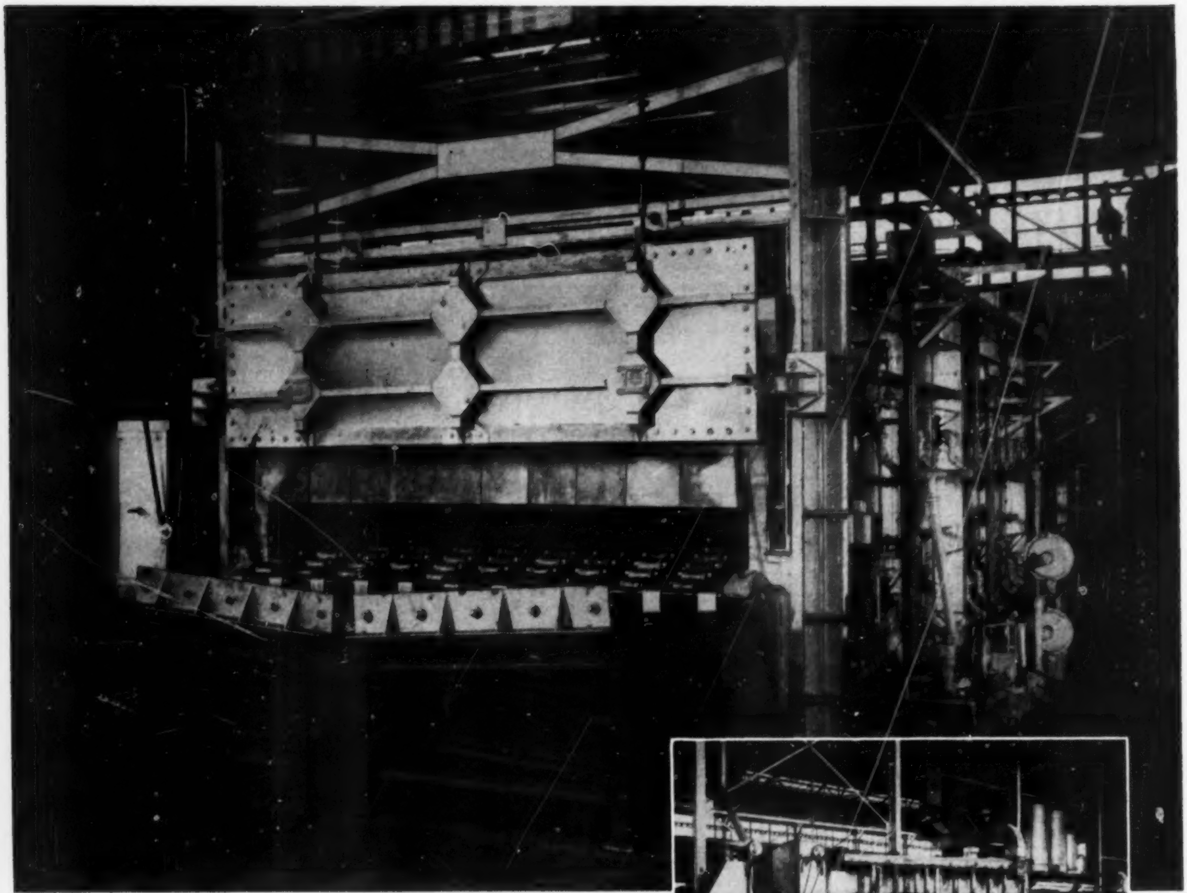
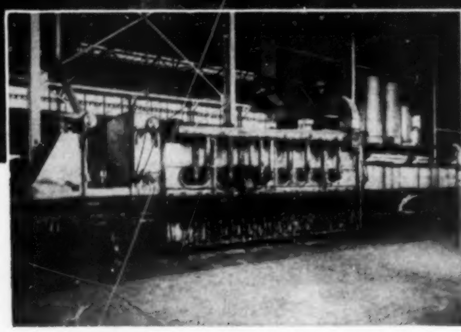


Gas-fired copper billet heating furnace, where billets are heated prior to processing.



Dempsey Gas-fired annealing furnace in the Los Angeles plant of Revere Copper and Brass Incorporated.

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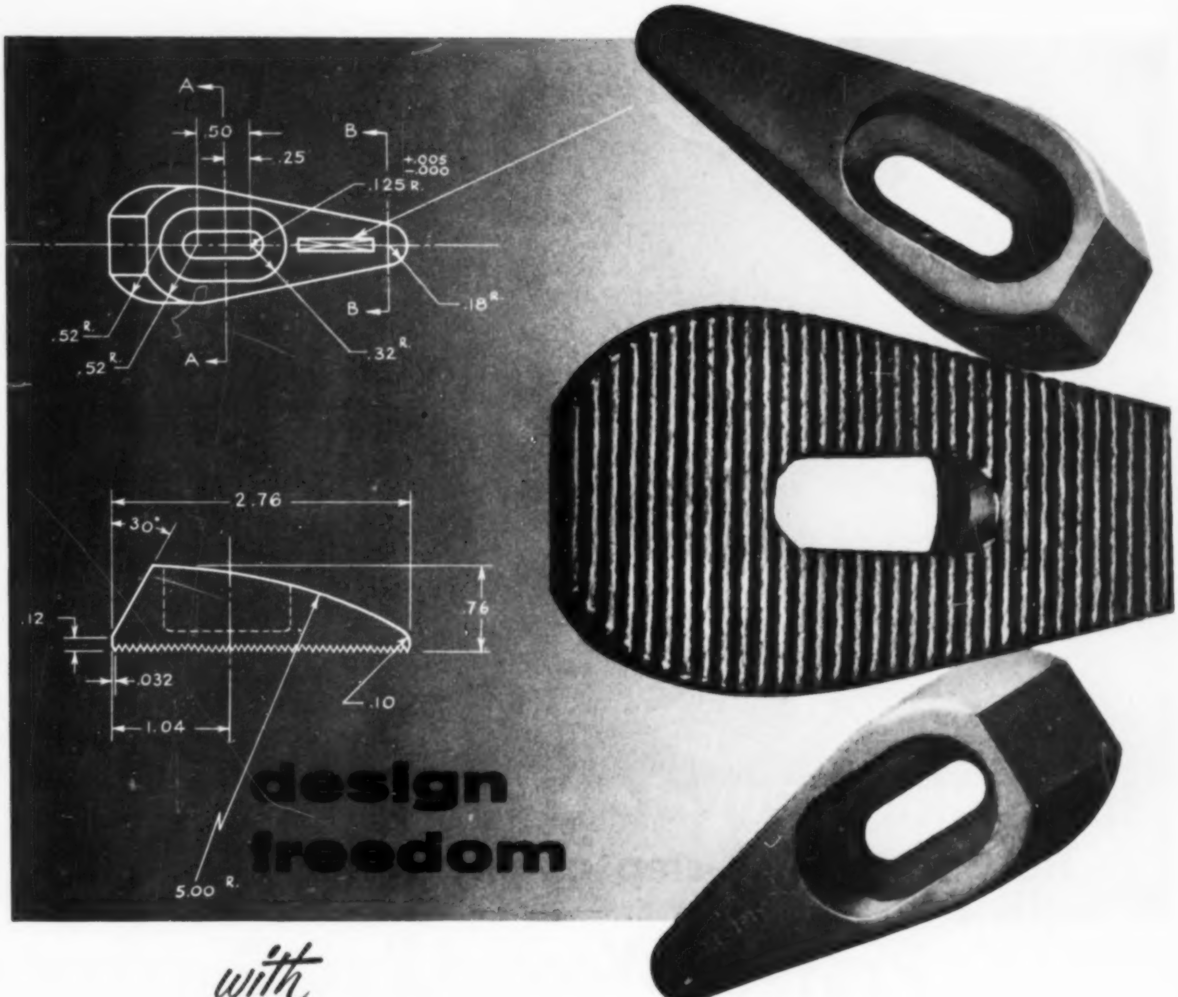
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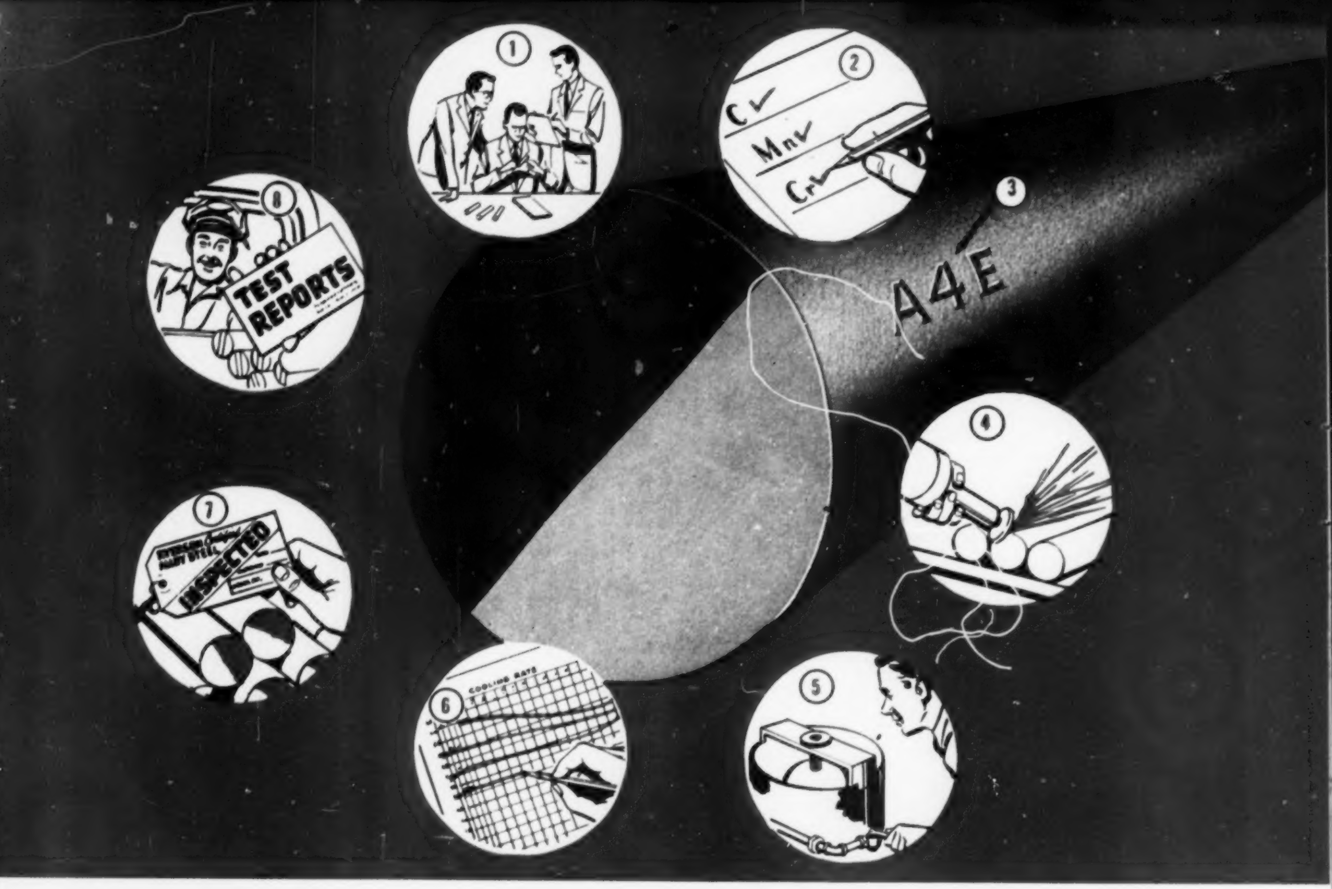
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Metal Progress

Volume 65, No. 4 **April 1954**

The first three articles in this issue of *Metal Progress* are condensed from contributions to the "Beryllium Symposium" presented with the cooperation of the U. S. Atomic Energy Commission during the ⊕ Midwinter Meeting in Boston, March 4 and 5, 1954.

Sources, Supplies and Uses of Beryllium

By ROBERT F. GRIFFITH, Commodity-Industry Analyst
Rare and Precious Metals Branch
U. S. Bureau of Mines, Washington, D. C.

Although the element beryllium was discovered in 1798, the beryllium industry was not established until the 1930's. Beryl, the only commercial source mineral of beryllium, is now recovered entirely by hand-sorting, but recently developed concentration processes show promise. Over 90% of our supply has been imported, largely from Brazil.

While beryllium oxide and metallic beryllium have important uses, the ability of beryllium to age harden copper has been responsible for its widest use. During World War II the largest use was in aircraft bearings, cams, gears, and bushings; since then the electrical and electronic industries have been the largest consumers of the metal.

Beryllium metal is an important material for the construction of nuclear reactors for the production of power.

The improved supply of beryl and resumption of commercial production by a second primary producer assure an increased and stable supply of beryllium products to American consumers; consequently many new and useful applications can be expected.

Beryllium is a comparative newcomer to the

Aerial View of the Luckey Plant of Brush Beryllium Co., Luckey, Ohio

ever-increasing list of industrially important metals. Although the beneficial properties of beryllium as an alloying agent were discovered in 1926, its widespread commercial application has developed only since 1941.

Beryl, the principal beryllium mineral, was prized as a gem as far back in history as 1650 B.C. Emerald, the green crystalline variety of beryl, is now more highly prized than diamond. Other gem varieties include aquamarine (bluish-green), morganite (pink), and heliodor (golden beryl). The oldest known mines are reported to have been in the Zabarah Mountains of Egypt.

The discovery of beryllium is credited to the French chemist Louis Nicholas Vauquelin who, in 1798, at the request of the French mineralogist Hauy, was attempting to determine the chemical similarity of beryl and emerald. (Pliny the Elder, the Roman scholar, in 50 A.D. realized that beryl and emerald are closely related.) In so doing, Vauquelin discovered the presence of a new element, which he first named "earth of beryl". The editors of the journal in which the first report was published suggested the name "glucine", because the sweet taste of the soluble salts was similar to glucose, but "glucinium" and its chemical symbol Gl have been superseded by beryllium and Be.

In 1828 Wohler in Germany and Bussy in France produced small, glistening spangles of metallic beryllium by reducing beryllium chloride with potassium. In 1898 the French chemist Lebau prepared the first beryllium of 99.5 to 99.8% purity by electrolysis of the fused salts, potassium or sodium fluoride and pure beryllium fluoride. However, this small production of dispersed particles did not solve the 100-year-old problem of a commercial process for extracting the metal.

SOURCE OF BERYLLIUM

Minerals – Beryl is now the only commercial ore, although at least 30 different beryllium-bearing minerals are known. Beryl is a beryllium-aluminum silicate and should contain about 5% beryllium, but because of alteration and inclusions the commercial grade of beryl usually varies between 3.5 and 4.2% Be. Granitic pegmatites (coarse, crystalline rock) are the only commercial source, and the beryl is recovered with feldspar, lithium minerals, mica, columbite-tantalite, and cassiterite. In some foreign countries where labor costs are low, deposits may be worked for their beryl content alone.

Beryl does not occur in large deposits, as do lead, zinc, and copper ores, for two reasons: First, the properties of the element beryllium are such that it is concentrated in appreciable quantities only in the late stages of solidification of molten magmas; consequently, the occurrence is spasmodic, erratic, and difficult to predict. Second, no successful commercial process for recovering beryl by mechanical means has yet been developed.

Helvite, a sulphosilicate of beryllium, iron, and manganese, is a possible source. It contains up to 14% BeO (5% Be). Large deposits are known in New Mexico, but concentration and extractive metallurgical processes are yet to be developed.

Recovery – Unfortunately, beryl has a density very near that of quartz, feldspar, and other common gangue minerals. For this reason, and because it fractures easily, beryl is not concentrated in placer deposits, and gravity concentration fails. Flotation, agglomerate tabling, dense-medium suspension, electrostatic separation, and nucleonic devices have all been tried, but no entirely successful commercial process has yet been developed. Consequently, all beryl is recovered by hand-picking ("cobbing"), and crystals or fragments less than 1 in. in diameter are seldom recovered. Probably not over an average of one third of the beryl contained in a deposit is recovered, although the recovery may be higher for individual coarse-grained deposits or when, as in Southern Rhodesia, the ore is washed, screened, and various sizes sent to their own picking belts, where trained natives sort out the beryl fragments as small as ¾ in.

The outlook for improved recovery is not as gloomy as the above statements might indicate. Bureau of Mines technologists at the Rapid City, S. D., station have developed a flotation process that eliminates expensive prior conditioning. It is now being tried in a pilot plant. Working on spodumene pegmatites from Kings Mountain, N. C., the Bureau has recently developed at Tuscaloosa, Ala., a reagent combination that retards beryl while floating spodumene. If byproduct beryl can be recovered from the large-scale spodumene mining operation at Kings Mountain, it could triple present domestic mine production of beryl (515 tons in 1952). This deposit is estimated to contain 300,000 tons of beryl mineral or equal to about 12,000 tons of beryllium metal.

Sources – The most significant conclusion from a study of the supply picture is the dependence of the United States on foreign sources. To emphasize our dependence on foreign sources of supply, known United States reserves of beryl in deposits now shipping and which can be recovered by present methods are less than 7000 short tons – less than three years' supply for commercial (other than governmental) uses, based on the 1952 consumption rate. During the period of 1936 to 1952, less than 10% of our total supply was derived from domestic mines. Brazil was the principal source and supplied 49% of the total, followed by South Africa and Rhodesia, 16%, Argentina, 11%, and India, 7%. Before 1936 India was the principal source of supply. Southern Rhodesia and South Africa have become important sources of beryl only since 1950, furnishing 43% of our total supply during 1950, 1951 and 1952. French Morocco and Madagascar have produced significant quantities of beryl during recent years; France received the bulk of it.

Discoveries of rich, localized pockets of beryl in various countries have resulted in wide fluctuations in production rates. For example, the beryl-rich mass in the pegmatite at the Las Tapias mine, Argentina, which provided most of the Argentine beryl, was exhausted after 3000 metric tons had been extracted. Known reserves and past production rates indicate that Brazil will continue to be the principal source. Salient statistics on beryl in the United States, 1936 to 1952, are given in Table I.

INDUSTRIAL DEVELOPMENT

Early in this century intensive investigations started simultaneously in the United States and Germany to develop a commercial process for the production of beryllium metal, alloys and compounds. Alfred Stock and Hans Goldschmidt in Germany and Hugh S. Cooper in the United States were instrumental in solving this 100-year-old problem.

In 1916 Cooper produced the first sizable ingot of beryllium in the United States that was suggestive of commercial application, and in 1918 he patented the beryllium-aluminum base alloy. Large specimens of the alloy, contain-

Table I – Statistics on Supply and Price
Short tons of beryl equivalent to 10% BeO

	1936-40	1941-45	1946-50	1951	1952
U.S. mine shipments	344	1210	1378	484	515
Imports	1759	13,872	12,346	4316	5978
Exports*	?	147	430	95	199
U.S. consumption	1800	10,524	8754	3388	3476
Domestic price	$2.84	$11.26	$18.83	$33.34	$38.55
Foreign price†	$3.76	$8.01	$17.84	$31.67	$38.55

*As beryl and beryl equivalent of metal in alloys or compounds.
†Per unit (20 lb.) of BeO.

Development of Beryllium Copper

ing up to 70% beryllium, both in cast and sheet form, were exhibited at the Philadelphia meeting of the Electrochemical Society in 1924.

Low Alloys – The ability of beryllium to age harden copper, in conjunction with small nickel additions, was discovered in 1926 by Michael G. Corson, a metallurgist at Union Carbide & Carbon Research Laboratories. Corson was most interested in beryllium-nickel-copper, and his patent covered that specific alloy only. The field of binary beryllium-copper and beryllium-copper-cobalt was covered by patents filed by his contemporaries in Germany, Masing and Dahl of Siemens & Halske A. G. This company did much research on beryllium alloys and first explained the precipitation hardening effect in beryllium copper.

In 1927 the Beryllium Corp. was organized at Cleveland. The work of its metallurgist, J. Kent Smith, in alloying beryllium with copper, nickel, gold, and iron induced the company to apply for patents. Interferences with those granted Siemens & Halske (assigned to Metal & Thermit Corp. of New York) were composed by these two American companies and the first significant domestic production of beryllium-copper was in 1932 by the Beryllium Corp. at its Marysville, Mich., plant. With the patent situation still unsettled, the Beryllium Corp. signed a contract with the Germans, providing for an exchange of information and patents and a hemispheric division of world markets.

The Brush Beryllium Co. was incorporated in 1931 to promote further investigations conducted since 1921 by the Brush Laboratories Co. of Cleveland. This company received its first substantial order for beryllium copper in 1934. Beryllium light alloys were advanced to commercial status in 1943 by Brush Beryllium Co., producer of the beryllium-aluminum master alloy, and by the Aluminum Co. of America, which processed and fabricated the master alloy of beryllium.

Clifton Products, Inc., of Painesville, Ohio, organized in 1939, produced high-purity beryllium oxide for fluorescent lamps and refractories, and started making beryllium flake in the year 1943.

The increased demand for beryllium-copper alloys in military applications in World War II required more capacity and all three of these plants were expanded. Industrially, the situation today is similar to that in the peak war years as to beryl consumption, total United States supply, and world production. However, at present beryl consumption is well below new supply, the difference going mostly to the national stockpile.

High Alloys and Beryllium Metal – The history of beryllium in atomic energy is thus recounted by R. E. Pahler of the A.E.C.'s Division of Reactor Developments:

"The early investigations on the use of beryllium for reactor purposes were sponsored by the Manhattan Engineering District, predecessor to the U.S. Atomic Energy Commission. Beryllium oxide and metal were purchased at that time under a unit price contract from Brush Beryllium Co., which manufactured these materials at Lorain, Ohio. In 1948 a fire destroyed this plant. The design of the materials testing reactor was well under way at the time, and an assured supply of high-purity beryllium was considered to be necessary for this reactor and other purposes. Consequently, proposals were solicited for the development of a metal manufacturing process and the design, construction, and operation of a plant. The Brush proposal was accepted and an oxide and metal production plant (capacity of several tons of 'pebble metal' per month) was constructed at Luckey, Ohio, starting production in January of 1950. Brush also operates a beryllium metal fabrication plant in Cleveland for the A.E.C. Clifton Products, Inc. operates a beryllium oxide fusion plant for the A.E.C. in Painesville, Ohio. The Beryllium Corp. of America operated a vacuum casting plant for the A.E.C. in Reading, Pa., but that operation has been discontinued; facilities are now available in the Luckey plant for this purpose."

DEVELOPMENT OF USES

Before beryllium alloys were developed, the principal use of the element was as an oxide for refractories, spark plugs, and high-quality electrical porcelains, and as nitrate for Welsbach gas mantles. These uses are still important. It was not until the early 1930's, however, that metallurgical improvements created a large enough demand to justify a "beryllium industry". Beryllium copper (with small additions of other alloying agents) was and continues to be by far the most important alloy. Commercially, hardened copper had its beginning in Waterbury, Conn., where in 1932 the American Brass Co. rolled beryllium-copper alloy sheets in its mill. Nickel-chromium-beryllium alloys and beryllium rustless steel were in limited use in

Europe in the 1930's but have not been adopted in the United States. Beryllium received some scientific and lay publicity in 1932 when the Englishman, James Chadwick, identified the neutron as the uncharged particles streaming from beryllium metal exposed to alpha rays from the radioactive element polonium. The use of the metal in radium-beryllium neutron sources followed. As early as 1936, disks made by compressing beryllium powder were used as windows for X-ray tubes, because of its transparency to soft X-rays. In addition to these two minor uses, beryllium metal has important atomic energy applications described by Mr. Pahler on p. 86 of this issue. Another spectacular, but short-lived, use of beryllium oxide was as a phosphor in the fluorescent lamp industry – discontinued in 1949 because of its possible health hazards.

Beryllium Copper – By far the largest tonnage use of beryllium since its early development and up to the present is in the form of beryllium-copper alloys. Two characteristics are largely responsible: First, beryllium-copper alloys are unsurpassed in their ability to withstand fatigue and wear, under high temperature conditions, and at the same time to conduct electrical current. Second, they are unique among copper-base alloys in that they can be worked in a relatively soft state and then brought to their final level of strength and hardness by simple low-temperature heat treatment. These properties immediately suggested numerous applications in electrical contacts and springs and in castings and forgings subjected to severe wear conditions.

At first, beryllium copper was primarily a competitor of phosphor bronze for springs and diaphragms and was early recognized as the most reliable spring material available. However, the largest tonnage during the early years went into nonsparking safety tools. Large quantities were shipped to all parts of the world for use in the petroleum and other industries where a spark from conventional steel tools might set off a disastrous explosion.

With the advent of World War II and the related demand for beryllium-copper products in military applications, the usefulness of this alloy was clearly established. Although the widest wartime application was for springs and diaphragms in instruments and electrical devices, the largest *tonnage* was in parts subjected to severe wear in aircraft engines. Often, design factors explained its use; in many aircraft instruments, beryllium copper allowed the use of a smaller (lighter) part. As many as 150 parts of an army field telephone were made of beryllium copper. Aircraft uses included engine bearings, cams, gears, bushings, and bearings and bushings in pitch propellers. In Germany, "hydronalium", an aluminum-magnesium-beryllium alloy with additions of manganese, titanium, and silicon, was used in air-cooled cylinder heads. Beryllium copper was used in piston rings and bushings for the Fiat motor manufactured in Italy.

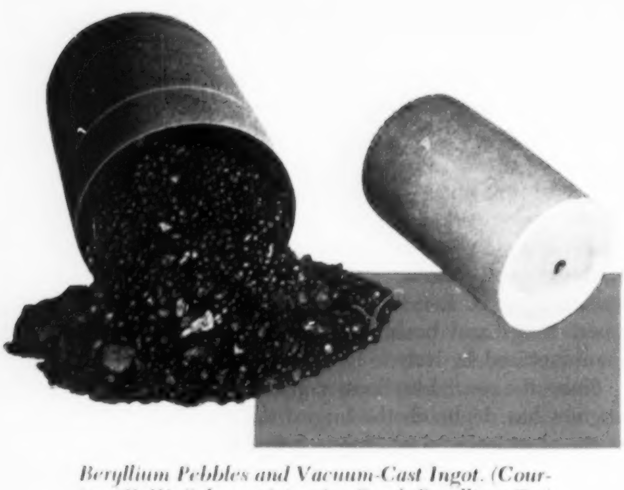
Since the war, beryllium copper in aircraft engines has declined; the largest usage is now in the electrical and electronic fields. Beryllium metal, which was formerly used only in small quantities for X-ray tube windows and in radium-beryllium neutron sources, has very important applications in atomic energy. More and more beryllium oxide is also being consumed in specialized high-temperature refractories and electrical porcelains. It is unique among ceramic materials in that its thermal conductivity at high temperatures is equivalent to or better than many metals, although it is an excellent electrical insulator.

OUTLOOK

The United States supply of beryl ore in 1952 and 1953 was the greatest in history. More basic material is now available to fabricators and users since the resumption of commercial production by Brush Beryllium Co. Consequently, an assured supply is now available to consumers.

In the past the supply has fluctuated greatly; periods of oversupply follow periods of acute shortages. This condition has made it difficult to develop a steady commercial market. For example, during times of emergency, when beryllium is used primarily for defense purposes, commercial users are forced to find substitutes. When defense demands decrease, a period of time is required to redevelop commercial applications. This lack of an assured supply from the primary producers has made manufacturers reluctant to adopt parts made of beryllium, despite the recognized fact that they offer superior qualities.

With this improved supply, it is certain that many new and useful applications of beryllium products will be forthcoming, and that the beryllium industry can look forward to a healthy future.



Beryllium Pebbles and Vacuum-Cast Ingot. (Courtesy C. W. Schwenzfeier, Jr., Brush Beryllium Co.)

Role of Beryllium in the Atomic Energy Program

BERYLLIUM is a metal of special interest for use in nuclear reactors. Nuclear reactors have been described so often that it is unnecessary to say more, in this place, than that they are devices to establish a controlled reaction wherein a free neutron (an elementary particle of matter carrying no electrical charge) strikes the nucleus of an atom of uranium-235 which thereupon breaks into fragments (other chemical elements) plus two or three more neutrons which are then available to carry on the process. Furthermore, the total mass of the particles resulting from each fission is less than the mass of the original U^{235} atom, and this missing mass reappears as energy.* The process is as diagrammed, simply, in Fig. 1.

Natural uranium metal (Element 92) is a mixture of three isotopes; 99.3% of them are $_{92}U^{238}$, 0.7% $_{92}U^{235}$ and 0.006% $_{92}U^{234}$. Obviously because of its U^{235} content it can be called a "fuel". Other fuels are $_{94}Pu^{239}$ and $_{92}U^{233}$, both manufactured from natural uranium and thorium, respectively. These fuels differ from each other in that some will absorb fast neutrons fairly easily, others are more receptive to slow neutrons; after that event some tend to split (fission), others tend to build up heavier, fairly stable elements. Thus it is that when natural uranium metal is used as the fuel for a nuclear reactor, a moderating material is required to slow down the "fast neutrons" as they burst forth from the fissioning U^{235} nuclei at speeds in excess of 10,000 miles per sec.† At such speeds their efficiency for fissioning other U^{235} nuclei is low, and they tend to be captured by the predominant number of U^{238} atoms present, which ultimately become Pu^{239} atoms. The physicists had learned that neutrons slowed down to "thermal" speeds are the most efficient for producing fission in U^{235} nuclei. Vastly oversimplified diagrams of what happens to a fast and a slow neutron are shown in Fig. 2 and Fig. 3.

Fast neutrons are slowed down, or moderated by random collisions with atomic nuclei. Nuclei of the lightest elements are the most effective moderators; an anology is that billiard balls lose their speed and energy more quickly in collision with other billiard balls than with heavier bowling balls. The fewer collisions involved in the slowing-down process, the more efficient the moderator. The number of collisions (scattering) required to slow down a fast neutron to thermal speed is as follows for various atomic nuclei:

Hydrogen	18
Deuterium	25
Beryllium	86
Carbon	114

*EDITOR'S FOOTNOTE – About 85% of it is kinetic energy of the flying particles (heat), and about 15% is electrical energy (consisting of particles of electricity, gamma rays and other impulses).

†EDITOR'S FOOTNOTE – This is about 1.6×10^9 cm. per sec. or one-twentieth the speed of light (3×10^{10} cm. per sec.). "Thermal neutrons" travel at speeds of about 2.2×10^5 cm. per sec., about four times the average speed of gas molecules at atmospheric temperatures and twice the speed of a bullet from a high-velocity rifle.

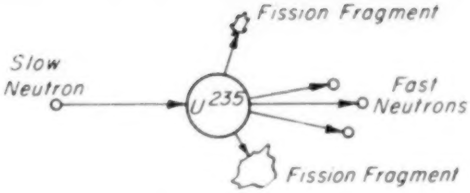


Fig. 1 – Diagram Representing the Results of a Collision Between a Speeding Neutron and an Atom of Uranium (More Specifically, a Nucleus of ${}_{92}U^{235}$)

This immediately indicates one important potential application of beryllium.

High density is to be preferred because of the larger number of atoms per unit volume. The moderator must be exceptionally pure in order to minimize neutron consumption by absorption. The scattering and absorption properties of moderators are measured by physicists in terms of their "neutron cross section", which is a property of the nucleus and of the energy of the incident neutron. Table I lists the major moderators*, with some of their properties.

There is another important function of a moderator when it can also act as a "reflector". The quantity of fissionable material required to maintain the chain reaction at zero power level is called the "critical mass". This can be decreased by surrounding the fuel core with a material which will moderate and reflect the neutrons back into the core and thus minimize the leakage of neutrons outside the system. A reflector material therefore effects a considerable saving in the fuel tied up in the reactor. The core volume of the reactor is also reduced and the power output is increased.

In a reactor core without a reflector the neutron flux density – number of neutrons passing any square centimeter per sec. – is at a maximum in the center of the core and falls off to near zero at the outer edge of the core. In a reactor core with a reflector, the neutron flux level is flattened and this increases the over-all power output, as illustrated graphically in Fig. 4.

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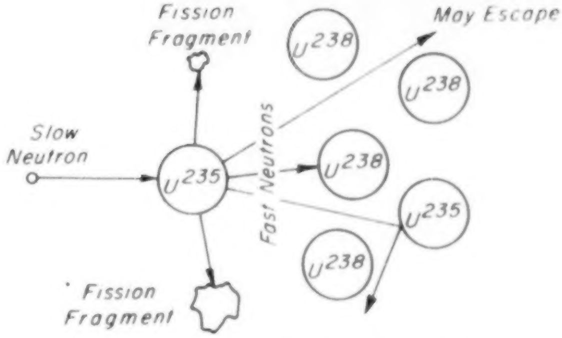

Fig. 2 – A Fast Neutron Coming From the Fission of U^{235} at One-Twentieth the Speed of Light Tends to "Bounce Off" Another U^{235} Nucleus in Its Path Without Causing It to Fission

COMPLEXITY OF THE REACTOR PROGRAM

The reasons why beryllium is of special interest for use in nuclear reactors have been explained; now let us take a rather brief look at the magnitude of a reactor development program. The basic principle of a nuclear reactor is quite simple; however, there are many reactor systems that can be built.

In the first place, a reactor can be constructed for any one of the following purposes: for production of fissionable material (plu-

*Editor's Footnote – The data in Table I are from the open literature and refer to thermal-type reactors. The plutonium producers at Hanford, Wash. are thermal reactors. If similar data could be presented for intermediate and fast neutrons, it would be apparent that beryllium is a very good moderator and reflector for thermal neutrons, fairly good for neutrons of intermediate speed, but no good for fast neutrons.

Table I – Cross Sections for Thermal Neutrons

Moderator	Density	For Scattering		For Absorption
		Barns* Per Atom	Barns Per Cc.	Barns Per Atom
Graphite, C	1.55 to 1.9	4.8	4.1×10^{23}	0.0045
Be metal	1.845	6.9	8.5×10^{23}	0.009
BeO	2.2 to 2.9	11.1	6.7×10^{23}	0.0099
Heavy water, D_2O	1.108	15.3	4.6×10^{23}	0.0009
Light water, H_2O	1.000	44 to 164	$15 \text{ to } 55 \times 10^{23}$	0.64

*A barn is 10^{-24} sq. cm.

tonium or uranium-233; for power; for a combination of power and fissionable material production; for radioisotope production; or for research purposes.

Several fuels can be used for these reactors: natural uranium; natural uranium enriched in uranium-235 to varying degrees; plutonium; or uranium-233.

The fuel can be used in various forms depending upon whether a heterogeneous or homogeneous reactor system is chosen. In a heterogeneous system the fuel can be alloyed and clad with some other metal or encased in a protective capsule to prevent the highly radioactive fission fragments from entering into the coolant stream which gives up its heat outside the shielded reactor core. In a homogeneous system the fuel can be dissolved or suspended as a solid (slurry) in a circulating fluid medium.

Finally, the reactor can be designed to operate in the thermal, the intermediate, or the fast neutron energy level.

When various combinations of these factors are made it is obvious that dozens of possibilities exist.

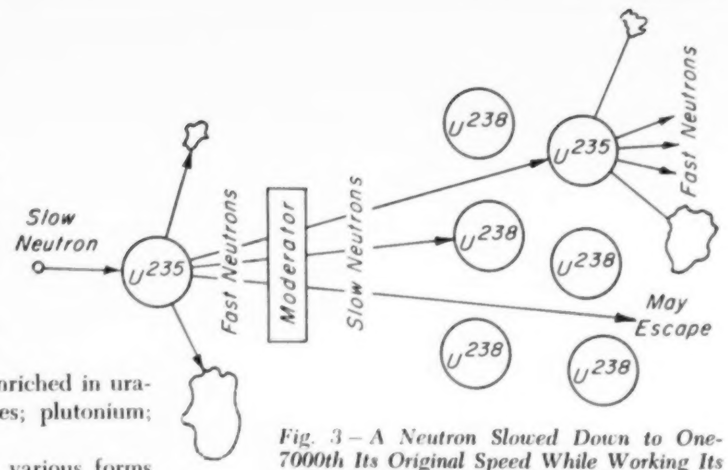

Fig. 3 – A Neutron Slowed Down to One-7000th Its Original Speed While Working Its Way Through a Moderator Is Readily Absorbed by Any U^{235} Atom in Its Path Causing It to Fission, and Thus Perpetuating the Reaction. Slow Neutrons absorbed by the heavier U^{238} nucleus transmute this element into plutonium, $_{94}Pu^{239}$, another fissionable element

DEVELOPMENT PROGRAM

There are many steps involved in a program for a specific reactor. A condensed version is:

A. Preliminary reactor design and evaluation.

B. Reactor physics and critical assembly studies.

C. Materials and components development.

D. Fuel element and fuel medium.

E. Developments in coolants, heat transfer, and power generation.

F. Development of instrumentation and control methods.

G. Shielding.

H. Chemical processing, waste disposal and treatment, and sanitary engineering.

I. Final design.

J. Construction program.

K. Pre-operational testing; training of operator; writing operating manuals.

Much developmental work is necessary, especially in Items C to H, because there is still a long way to go to satisfy the needs of the reactor physicists and design engineers in developing the reactor complex. Steps C, D and G involve the testing and evaluation of reactor materials. Knowledge about reactor materials and their behavior in reactors is still very limited; however, considerable additions are being made every day.

Requirements of Materials for Reactors – By definition, a reactor material is that which is used in the fabrication of fuel elements, moderators, reflectors, structural components in and around the core, control rods, and shielding materials. An ideal reactor material (fissionable material excluded) should meet as many of the following requirements as possible:

1. Low atomic weight so that the impact energy of neutrons is reduced rapidly. (This applies to moderators only.)

2. Low parasitic capture cross section and no tendency to have a high induced activity (radioactivity) as result of parasitic capture.

3. Adequate structural strength under the temperature and irradiation conditions encountered.

4. Resistance to corrosion of coolant medium.

5. Dimensional stability.

6. Good heat transfer properties.

7. If used in fuel elements: good bonding and minimum diffusion between the fuel and the clad material.

8. Low cost; amenability to rigid fabrication specifications.

Requirement No. 2 does not apply to control rods, which are made of high cross-section materials that absorb a large number of neutrons. When the control rod is moved into the core all the way, the chain reaction dies. If the control rod is withdrawn too far the neutron flux increases exponentially, as does also the heat generated within the reactor. The reactor

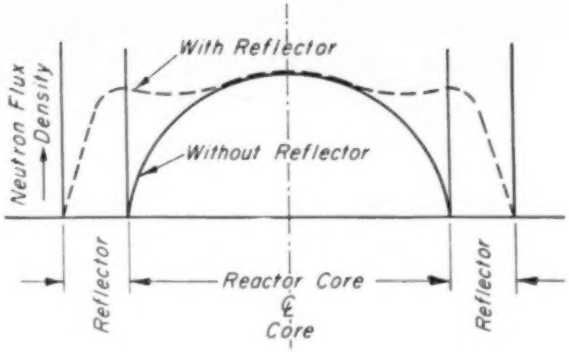

Fig. 4 – Variation of Neutron Flux Density Across Reactor (a) *Without a "Reflector" and* (b) *Surrounded by a "Reflector"*

control rod is an important mechanism and precise manipulation is imperative. It is apparent that if the control rod fails and the power output of the reactor increases very rapidly, the heat-removing capacity of the system must also increase accordingly, else damage or even disaster will occur.

BERYLLIUM AS A MODERATOR AND REFLECTOR

Unfortunately, there is no one material meeting all the above specifications. Beryllium metal is no exception.

For security reasons I am permitted to discuss only two of its present or proposed applications. Beryllium metal will be used in the Submarine Intermediate Reactor (SIR) now being constructed at West Milton, N. Y. by the General Electric Co., which operates the Knolls Atomic Power Laboratory as contractor for the U. S. Atomic Energy Commission. Some information about the Materials Testing Reactor (MTR) at Arco, Idaho, has been declassified; consequently, I can discuss this specific application of beryllium in some detail.

The MTR* was designed as a research tool for exposing reactor materials to high intensity of radiation. It is a thermal reactor using enriched uranium as fuel, light water as both moderator and coolant, and beryllium as a reflector. It is designed to operate at a power level of 30,000 kw., and supply the highest neutron flux of any known reactor. Design and development started in December 1945; ground was broken in May 1950; it reached full design power on May 22, 1952; and has been operating smoothly since that time. Phillips Petroleum Co. operates it under contract with the A.E.C.

In the MTR design and development stage there were many, many problems to be solved concerning beryllium. Its corrosion resistance and its mechanical and fabrication properties were unknown. At that time beryllium was available commercially in the form of pebbles. The pebbles had to be vacuum cast into billets which were then extruded to the desired shapes. The extrusions were difficult to machine to the reactor tolerances required, because there was a tendency for the beryllium crystals to tear out of the surface, especially at the corners.

A powder metallurgy technique (described by Wallace W. Beaver of Brush Beryllium Co. in this symposium) for fabricating the shapes to rigid specifications was then developed. The pebble metal is vacuum cast into an ingot. The ingot is reduced to a powder in two steps: (*a*) turning in a lathe and (*b*) grinding the turnings in an attrition mill. The fine powder is compacted and sintered under pressure and elevated temperature for several hours. The large sintered shapes are then cut up into rough shapes and finish-machined to the final close tolerances required.

Beryllium shapes as large as 4⅜x20x64 in. have been made by this process, the large size often making for lower fabrication costs of the required part.

Considerable heat is generated within the large beryllium blocks in the MTR due to the absorption of energy from the fast neutrons and gamma rays. This heat has to be removed continuously, so water coolant channels were provided. There was a possibility that the temperature differentials in the beryllium would be sufficient to set up stresses large enough to crack the blocks. The channels were finally so located that the maximum thermal stresses in the block are well within the tensile strength of beryllium.

Chemical specifications for the beryllium used in the Materials Testing Reactor were very rigid. Impurities with a very high absorption cross section were most undesirable. For example, one part per million of boron (absorption cross section of 750) is equivalent to 903 parts per million of nickel (cross section 4.5), 8500 of aluminum (0.22) or 1610 of iron (2.4).

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*Specific details of the MTR are contained in "The Materials Testing Reactor as an Irradiation Facility", by J. R. Huffman; Report to Atomic Energy Commission IDO-16,122-PPCo, Aug. 31, 1953. Copies may be obtained from Phillips Petroleum Co., Idaho Falls, Idaho.

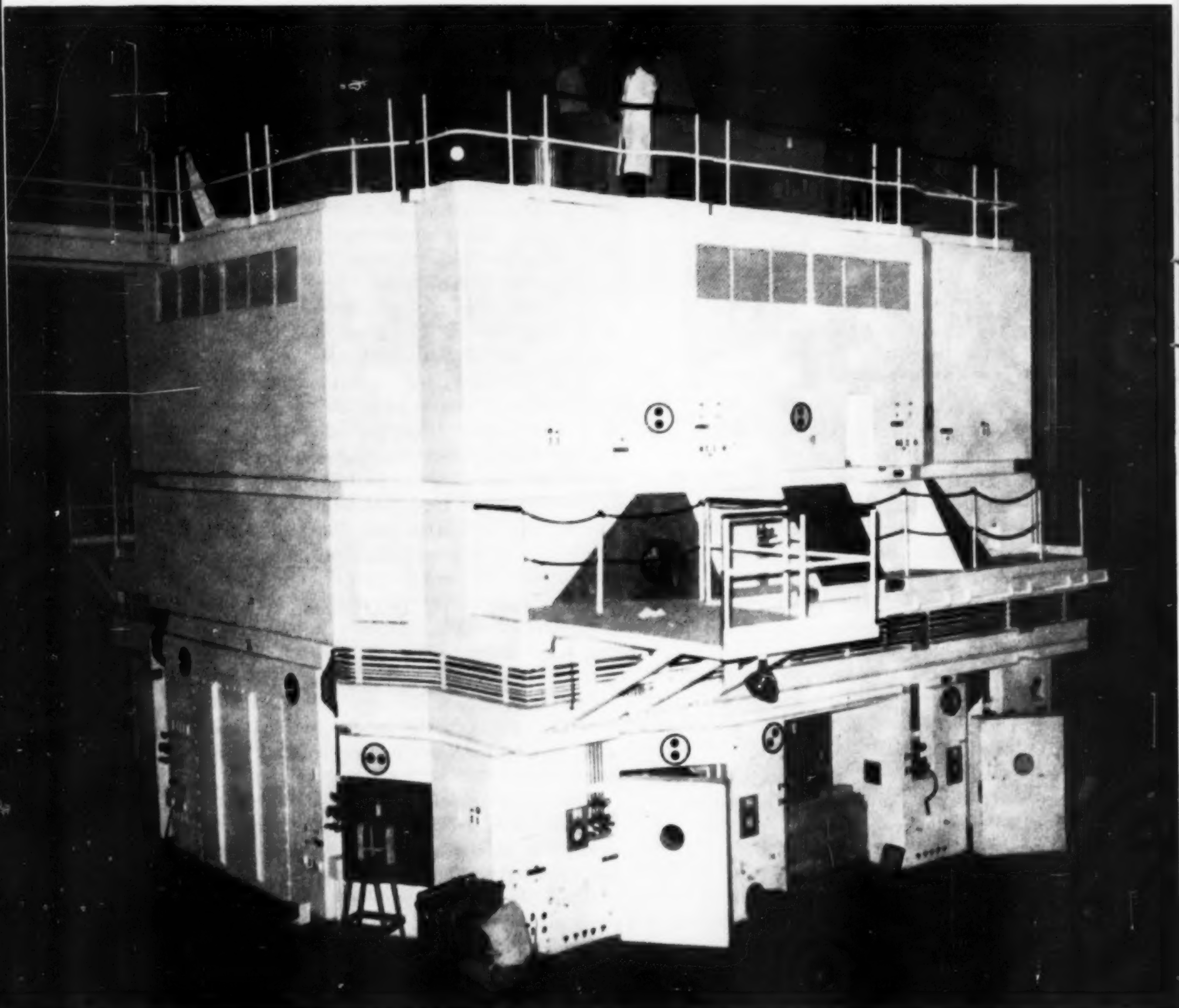


Fig. 5 – The MTR (Materials Testing Reactor) at Arco, Idaho, Utilizes Beryllium as a Reflector

The physicists were concerned with neutron economy in the beryllium – parasitic capture by impurities. Likewise the design had to permit removal of some of the irradiated beryllium blocks so that experiments could be conducted within the reflector; high induced activity in the blocks due to the presence of certain impurities would have required special shielding and devices for making such adjustments. The impurity tolerances in the MTR beryllium are therefore specified in parts per million; however, there is good reason to believe that in the future the physicists will relax on some of the impurity specifications after more reactor experience is gained. In other reactor applications where the beryllium blocks are not removed the induced activity would not be a problem; then it becomes a question of balancing neutron cost against purification costs.

FUTURE DEVELOPMENT

If the following objectives can be accomplished, beryllium will play a much more important role in the reactor program:

1. Adequate ductility, so it can be used for

fuel elements and for structural components.

2. Low cost, so beryllium does not represent a substantial part of the total reactor cost.

3. Increased supply of beryl ore, so there is no question of availability when one considers reactors that will be built in large numbers.

Ductile Beryllium – It has been reported that ductile beryllium has been made but no one has been able to duplicate those results consistently. These claims provide some hope. As a matter of fact, both A. R. Kaufmann of Massachusetts Institute of Technology and Wallace W. Beaver of Brush Beryllium Co. have demonstrated ductility in one direction in compacted and sintered beryllium metal which has been extruded. Considerable effort has been put forth in preparing high-purity metal; however, its ductility has been discouraging. There is still the hope, however, that some day sufficiently pure metal will be prepared to prove whether or not it is inherently ductile. If ductile metal is prepared, the next step will be to develop a production-scale purification technique so that the final cost of the product is not prohibitive.*

Much effort has been put forth in the development of a ductile beryllium alloy† but the results to date have been discouraging. If a ductile alloy high in beryllium can be found and it meets the requirements of an ideal reactor material, its use in reactors will advance appreciably. A slight sacrifice in cross section due to the presence of the alloying elements will be more than offset by good ductility.

Cost of reactor beryllium is high because of high cost of beryl ore, low recovery of metal from the ore, low volume of production, high purity specifications, expensive fabrication techniques, low volume of fabrication, rigid specification for the finished reactor components, and costly health measures. (In some of the plant operations the cost of the health control measure is offset by the value of the additional beryllium recovered.) Cost improvements in many of these categories have been effected; however, there is much more to be done to improve beryllium's role in the atomic energy program.

At present the A.E.C. is the major consumer. Some metal is used in the manufacture of windows for special X-ray machines, and a small amount is used for industrial research. These are relatively small in comparison to the A.E.C.'s annual use. On the other hand, the annual production is insignificant compared to the other metals like aluminum, magnesium and copper. The cost would be reduced automatically if produced in comparable amounts, but this cannot occur until there is a large industrial demand.

There is one possible answer. Beryllium-copper master alloy, consumed in industry in considerable tonnage, is made by placing a mixture of copper, BeO and carbon in an arc furnace. The carbon reduces the BeO to beryllium metal, which in turn alloys with the copper. This particular grade of BeO costs about $21 per lb. of beryllium content, and the beryllium value in the master alloy is about $40 per lb. If a cheaper method can be found for producing Be-Cu alloy using beryllium metal rather than BeO, and if this metal meets reactor specifications, both the beryllium-copper industry and the reactor builder will benefit.

Even though beryllium is the lightest structural metal, it is not considered in aircraft applications because it is not ductile. Titanium is recognized as an excellent structural material for military aircraft because of its high strength-to-weight ratio. If ductile beryllium can be found and if its tensile strength is comparable to that of the present beryllium, it will be much more attractive than titanium because its strength-to-weight ratio will be 30% greater.

If these various potential uses for ductile beryllium are added together there should be a sufficient requirement to warrant a reasonably large scale of production with a corresponding low cost.

THE TARGET

In closing, I would like to repeat once again that the reactor builders are interested in low-cost beryllium and adequate supplies. This can best be accomplished by industry, since industry is in a position to find other large industrial uses. It will take considerable time to promote these uses, so let me cite some costs which would be attractive now in reactor applications. (The writer has to be somewhat speculative in this, but the commercial availability at the costs cited would be welcomed by reactor physicists and engineers.)

1. Raw beryllium metal of reasonable purity at less than $25 per lb.

2. Simple beryllium shapes made by powder metallurgy techniques for less than $50 per lb.

3. Ductile beryllium ingots costing in the neighborhood of $30 per lb.

*Editor's Footnote – Time was not so long ago that commercially pure zinc was "too brittle" to roll into sheet.

†See "The Metallurgy of Beryllium", *Transactions* of the American Society for Metals, Vol. 42, 1950, p. 785.

Fabrication of Beryllium by Powder Metallurgy

By WALLACE W. BEAVER, Director of Process Development
The Brush Beryllium Co., Cleveland

[In the paper presented at the Symposium on Beryllium immediately preceding this one, C. W. Schwenzfeier, Jr., vice-president of Brush Beryllium Co., described the process for extracting metal fluoride from its ore. This pure fluoride is then reduced by magnesium and the pellets of 99.5% beryllium are vacuum cast into 50-lb. ingots, ready to start powdering and reconsolidation, as will now be described by Mr. Beaver.]

Powder metallurgy as a basic fabrication technique is generally limited to those elements too refractory for foundry techniques. Beryllium is somewhat unique in that, despite its relative fusibility, its commercial fabrication is by powder metallurgical processing – principally to give it a fine-grained structure and to develop mechanical properties sufficient to withstand subsequent fabrication operations.

Early experimentation resulted in brittle, low-density compacts, largely because of the high slag content of the powder. When the possibility of fabricating beryllium in relatively large quantities became evident in 1945, foundry and vacuum techniques warranted intensive study; however, because of size limitations, properties, and only fair reproducibility, these processes were not acceptable, and powder metallurgy became the sole fabrication process.

Dense beryllium with fine grain was produced in 1946 by crushing and grinding beryllium pebble to fine powder and pressing under vacuum. However, because slag was still present in small quantity, the billets suffered from intergranular corrosive attack.

Present production technique involves the vacuum melting of pebble into cast ingots largely for removing slag and magnesium. The ingots in turn are comminuted to powder. Such powder is now commercially available for fabrication operations involving hot pressing or mechanical working. Strength and ductility of the beryllium parts depend on a fine grain size, which can be controlled primarily by the size of the original particle.

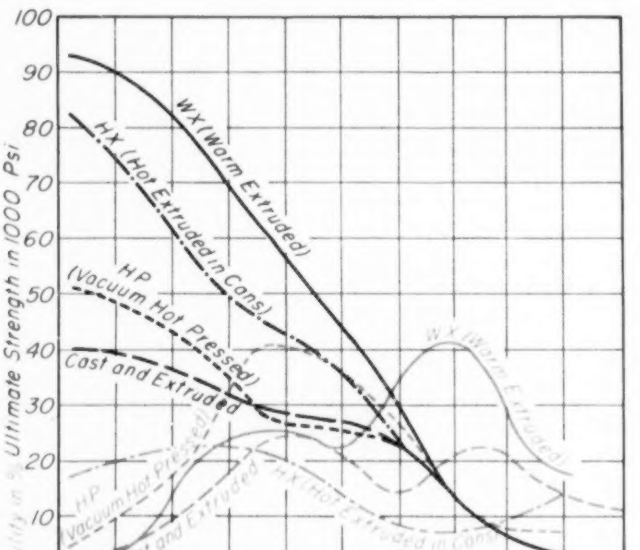


Fig. 1 – Tensile Strength and Ductility (in Color) of Various Types of Beryllium Extrusions, Three Starting With Comminuted Powder, One starting as Vacuum-Cast Ingot

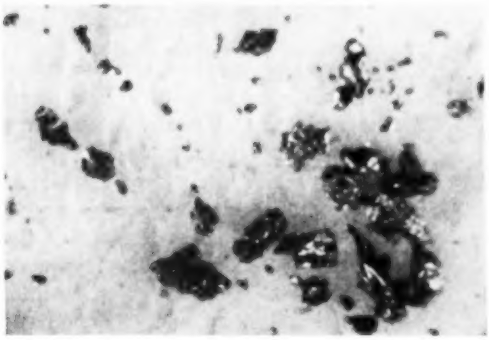


Fig. 2 – Size and Shape of Attritioned – 200-Mesh Beryllium Powder. 60×

There are several basic processes used for further handling. These may involve cold compacting, sintering, and warm or hot mechanical working; or hot mechanical working directly from the powder (usually enclosed in welded steel envelopes); vacuum hot pressing at low pressure; and atmosphere hot pressing at high pressure; as well as any combination thereof. Consequently, one may say that any feasible powder metallurgical method would be of interest for beryllium.

Ultimate strengths and ductility of various fabricated forms are compared in Fig. 1. The attritioned powder was extruded in steel cans at temperatures above the recrystallization temperature (tests marked HX) as well as below the recrystallization range (WX).

Beryllium produced from powder by Brush Beryllium Co. is known as "Q" type metal, the commercial product at the present time being designated as "QMV" (comminuted vacuum-cast pebble).

POWDER PREPARATION

Production of powder is by chipping 50-lb. vacuum-cast ingots by a multiple turning operation followed by attritioning to –200-mesh powder. This grinding is done in dry nitrogen in an attrition mill having water-cooled plates faced with beryllium. A certain amount of the powder from the first pass through this mill is under 400 mesh, and these fines contain a rather large amount of the impurities in the original ingot. A vibrating screen is placed in the bottom of the completely closed mill, and the oversize is returned to the top of the mill. A number of passes are necessary for complete grinding. Reduction much below 8 to 10 microns is impracticable without excessive contamination from the equipment and oxidation of the powder. A little over half of the final product is –325 mesh.

Because the character of the particles influences its fabrication characteristics and also the properties of the finished pieces, the powder's analysis, surface area, shape, and surface condition are of paramount importance. The chemical analyses of two types are as tabulated below. High-purity powder comes from vacuum castings especially selected for their analyses. Figure 2 shows this powder at a magnification of 60×.

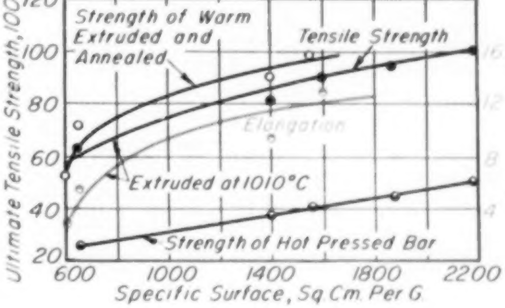
ELEMENT	STANDARD	HIGH-PURITY
Beryllium	99.0 to 99.6	99.4 to 99.8
Iron	1500 ppm.	400 ppm.
Silicon	500	300
Aluminum	500	100
Magnesium	500	50
Carbon*	720	440
Oxygen*	5700	5700

*Probably occur as compounds with beryllium. Oxygen goes up as average particle size decreases.

Variation of Powder Type; Handling of Powder – When comparing vacuum-cast powder of standard analysis with particles made by electrolysis, vapor-phase reduction and other methods in regard to as-fabricated mechanical properties, the standard QMV powder gives considerably greater elongation and ultimate strength than do the other materials. Although these may be lower in metallic impurities, the nonmetallic content of the as-reduced powder sponge and flake (chiefly slag) is higher than that of vacuum-cast and attritioned powder and contributes to both low strength properties and brittleness.

To obtain information relative to the effect

Fig. 3 – Relation of Tensile Strength and Elongation to Original Particle Size of the Beryllium Powder, Hot Pressed Before Extrusion. Top line represents tensile strength of hot pressed bars, extruded at 450° C. (840° F.) and annealed at 750° C. (1380° F.)



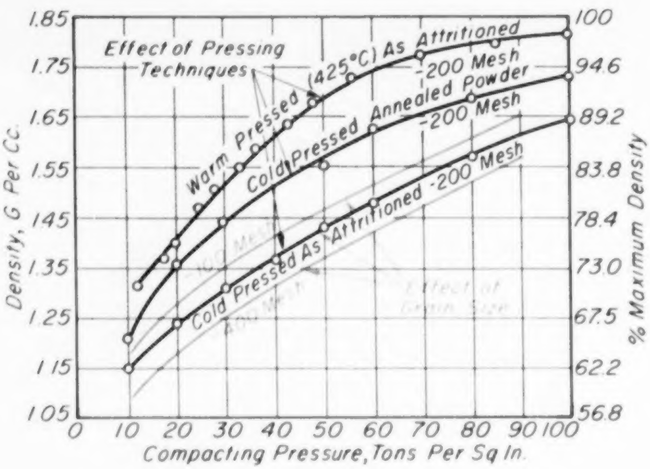


Fig. 4 – Three Lower Curves Show Effect of Particle Size on Cold Pressing Characteristics of QMV Commercial Standard Beryllium Powder, as Attritioned; Curves in Black Show Effect of Annealing the Powder and of Warm Pressing at 425° C. (800° F.) on 0.5-In. Diameter Test Pieces

of oxygen alone (when not present with slag), samples of powder of constant size and purity were oxidized, or mixed with beryllium oxide. Other chips and pebbles were ground to very low oxide content under dry helium (dew point −85° F.). Low oxide caused no increase of tensile elongation. On the other hand, with analyses much above 2% BeO, it was extremely difficult to produce full density by hot pressing alone. It was concluded that at −200 mesh little advantage or disadvantage is found by varying the oxide content in the range 0.5 to 1.5% BeO. Apparently, higher oxides can be tolerated when mechanically working powders than when hot pressing them.

Oxygen pick-up from moisture adsorption during storage is quite important. If stored in closed containers or under drying agents, no change in oxide can be detected. Under normal room conditions and temperatures an oxide-free powder will, after 10 weeks in the open, show an increase of about 0.25% BeO through water adsorption. More than three quarters of this can be eliminated by drying at a temperature of 100° C. (212° F.).

The pronounced effect of fine grains in favoring high tensile strengths and elongations at room temperature is shown in Fig. 3 for mechanically worked powder. To a large extent, grain size in the final metal is primarily a function of particle size in the attritioned powder, since the oxidized surface of the particles restricts grain growth at temperatures in the normal sintering range.

CONSOLIDATION OF POWDER

The major criterion for the initial evaluation of quality of finished parts is their density. Acceptable figures are usually 1.83 to 1.845 g. per cc. (Theoretical density runs from 1.845 to 1.855, with normal impurities. Practically all impurities will increase the density.) In many respects, however, it is better to work to lower densities in initial consolidation if the compacts are to be worked further.

Vibration Packing – The packing density of loose powder is usually a function of the grain size distribution and shape of the particles. Shapes approaching spheres, and coarser particles with narrower mesh distribution, develop better packing characteristics.

The most useful method for consolidating powder before application of mechanical pressure is by vibration at 60 cycles. Attritioned −200-mesh beryllium powder with density 39% of theoretical maximum can be increased to 52% in 4 min. vibration (about one third).

Pressing – The effect of grain size on the cold pressing characteristics of beryllium attritioned from vacuum-cast metal is shown in the three lower curves of Fig. 4, indicating that the densification rate under pressure, as well as the initial packing density, is higher for powders containing coarser particles. Under improved surface lubrication conditions, as well as with shorter compacts, higher density can be reached in the cold-pressed condition. Also, attritioned powder which has been annealed gives higher densities, and pressing at higher temperatures will increase the density still further, as shown by the black lines in Fig. 4. Pressure required to reach a given density decreases as the temperature in the mold increases.

A vacuum not only protects the powder in high-temperature pressing, but also decreases the required pressure. Pressures as low as 100 psi. can be used with a 50-micron vacuum. However, to achieve full density in the open atmosphere, 1500 to 2000 psi. is needed. Unlike cold pressing, in vacuum hot pressing the required compacting pressure dropped as the grain size diminished.

The greatest portion of the total operating time consumed in consolidating powder at high temperatures is used for heating; in most cases, only 1 to 5% of the total is consumed in compaction. At higher temperatures, less time is needed to apply pressure, but more, propor-

tionately, is required for thermal equilibrium. One to five minutes may be needed at 1000° C. (1830° F.) with pressures over 1 ton per sq.in. Upon decreasing the temperature to 800° C. (1472° F.), the time increases to about 10 min. Time also decreases with higher pressures. The longest pressing times (one hour or more to compensate for the low pressures applied) are needed for vacuum hot pressing.

Density Variation – When producing large pieces, especially shapes with high length-to-diameter ratios, the density may vary along the pressing axis, as shown by the following table relating pressure on the punch in tons per sq.in., temperature of the mold and powder, and percentage of maximum density one diameter and four diameters from the punch.

Pressure	Temperature	Density 1 D. Down	Density 4 D. Down
27	460° C.	77.6%	71.2%
45	430	87.3	81.5
63	425	90	86.5
90	375	92.9	89.7
81	425	94.7	91.8
100	460	95.7	93.4
100	425	98.7	97.2

At higher pressures and lower L:D ratios, this variation decreases. Improvements in die lubrication, as used in the test recorded in the last line of the table, not only increase the maximum density obtainable, but decrease the variation along the compact. Since density progressively decreases with distance from the punch, pressing from both ends would decrease these variations. The limiting factor is the ability of die materials and lubricants to withstand pressure and temperature without contaminating the product.

Sintering – In general, beryllium cannot be sintered effectively below 1050° C. (1920° F.); to substantially increase the density, more than 1100° C. (2010° F.) is needed. When compact density (in g. per cc.) after sintering is compared with original density of the compact, a low sintering temperature (1100° C.) and high initial density may result in an expansion rather than contraction. At higher sintering temperatures considerable shrinkage may be expected even with much lower initial compact density, approaching a maximum at about 1200° C. (2190° F.). See table on following page.

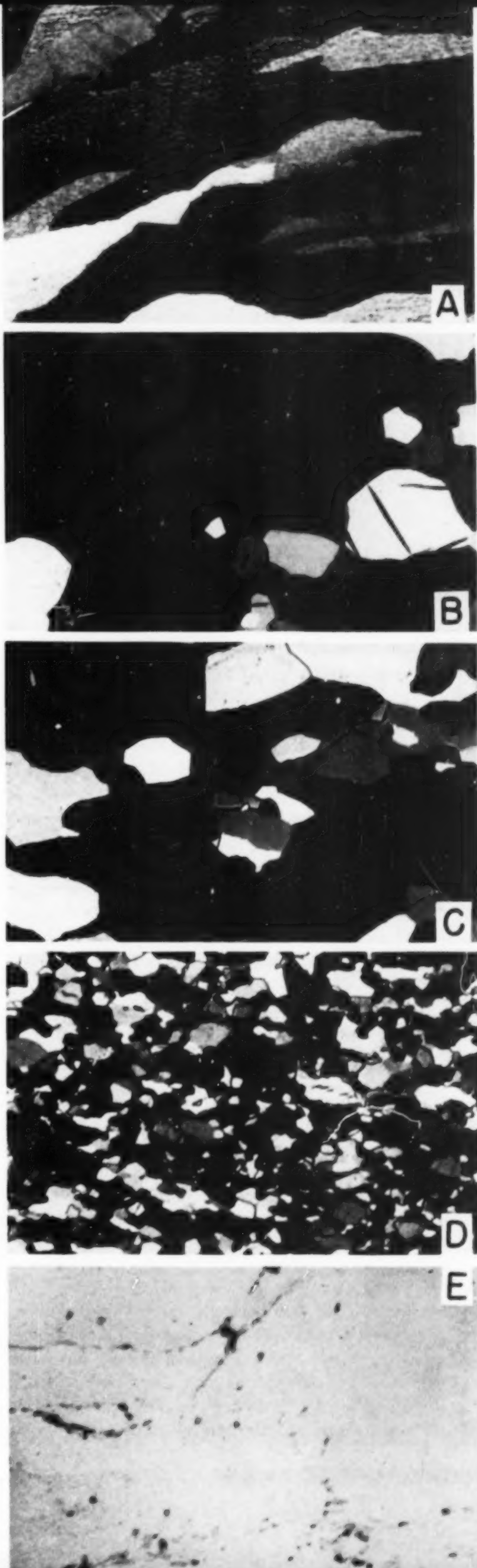


Fig. 5 – Relative Grain Sizes of Various Stages of Beryllium Powder Manufacture. (A) – Vacuum cast, 6×. (B) – Hot pressed chip, 125×. (C) – Hot pressed, first pass powder, 125×. (D) – Hot pressed, –200-mesh powder, 125×. (E) – BeO on compacted grain boundaries, unetched, 1250×

Fig. 6 – Large Horizontal Vacuum Hot Pressing Unit

Temperature	Time	Compact	Sinter
1100° C.	2 hr.	1.225	1.30
		1.355	1.445
		1.70	1.72
		1.83	1.815
1150° C.	2 hr.	1.36	1.665
		1.44	1.755
		1.545	1.77
1200° C.	20 min.	1.575	1.835

Very little grain growth is observed after sintering the standard –200-mesh powder (less than 50% increase in grain diameter), provided temperatures are under 1175° C. (2150° F.). Powders with smaller grain size (increased specific surface), carry increasing amounts of beryllium oxide which serve as an effective barrier against grain growth, despite the increased surface energy of smaller particles tending toward grain growth. At temperatures approaching 1200° C. (2190° F.), instantaneous grain growth can occur, the exact temperature being dependent on the amount and character of this oxide layer, since this growth apparently takes place on its breakdown. This seems to be the reason why hot pressed or mechanically worked QMV beryllium powder retains a fine and relatively stable grain size, unlike the coarse grains in cast beryllium (Fig. 5).

Major difficulties with cold pressing are the high forces involved and the blistering subsequently caused by trapped air in the interstices (unless sintering is done under vacuum). Pressure must be added to the sintering operation to achieve densification without exceeding temperatures for rapid grain growth. This, in essence, is the basic vacuum hot pressing technique used commercially for beryllium.

Effect of Atmosphere–At temperatures below 800° C. (1470° F.) massive beryllium need not be protected from the atmosphere; below 600° C. (1110° F.) even beryllium powder does not oxidize very rapidly in air. At higher temperatures, exposure to oxidizing conditions should be brief with as little surface exposed as possible. In powder forging, or high-pressure hot pressing, loose powder should be protected by inert gas while being heated in a container. The beryllium may then be exposed to open air momentarily (1 to 2 min.) with not more than 20% increase in oxide. At temperatures above 600° C. loose powder is usually handled under vacuum–that is to say, in the vacuum hot pressing process. To avoid contamination, not only from the air but from graphite or metal dies in coining and hot pressing, the powder is pre-compacted by warm or cold pressing, thus reducing the surface attack to the outer periphery. In other processes, the powder is protected by steel cans, evacuated and then welded shut.

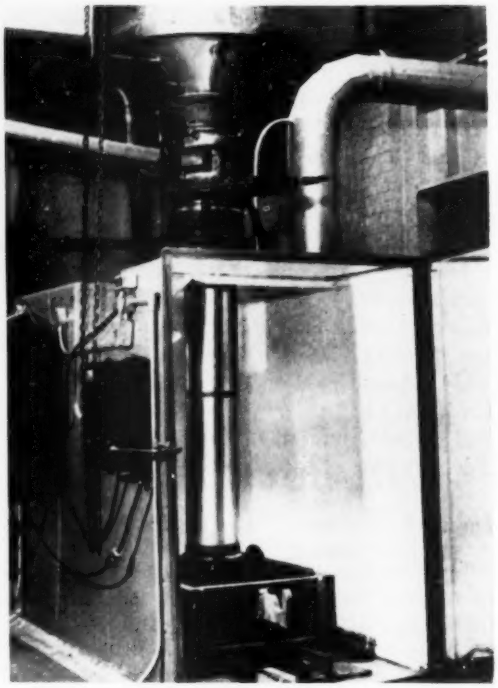


Fig. 7 – Cabinet and Equipment for Filling a Die With Beryllium Powder

At temperatures in the warm pressing range (300 to 700° C.) less protection is needed and canning is unnecessary. However, it is still well to operate with a pre-compressed body. Beryllium can be handled without protection at much higher temperature than is generally credited. Apparently, the oxide film is rather passive and protects the underlying metal against oxidation below about 825° C. (1515° F.). Above this temperature the film breaks down and metal is exposed.

FABRICATION METHODS

Inasmuch as a large number of variables exist (such as temperature, time, particle size, powder analysis) considerable care must be exercised in the choice of operational procedures. Generally, economics as well as quality make it imperative to consider three further factors:

1. Shape and size desired.
2. Number required.
3. Dimensional tolerances, chemical analysis and mechanical properties of the part.

Economics generally demand a shape as close to final dimensions as possible to avoid devaluation of metal as scrap. An alternative is to treat the material in such a manner that the excess beryllium may be recycled into the fabrication stream with little depreciation from the powder value.

Three groups of processes are available:

1. Consolidation of large billets which are brought to final dimension by machining. The billets can be made by vacuum hot pressing at low pressure (50 to 250 psi.) or by direct pressing of semiconsolidated powder without protection from the atmosphere at medium pressure (1000 to 10,000 psi.).

2. Direct production of shapes as near to final density and dimension as possible by (*a*) warm pressing or coining (high pressures), (*b*) high-temperature pressing of powders without atmospheric protection (medium pressure), (*c*) hot coining subdensity compacts at medium to high pressure, and (*d*) forging powder at elevated temperatures (using medium pressures).

3. Fabrication of semifinished bodies into such shape and form that they could be brought to final dimension by mechanical deformation (extrusion, forging, rolling). Any method listed under 1 and 2 may be used.

(Continued on p. 168)

Fig. 8 – Die and Plunger Used in Vacuum Hot Pressing

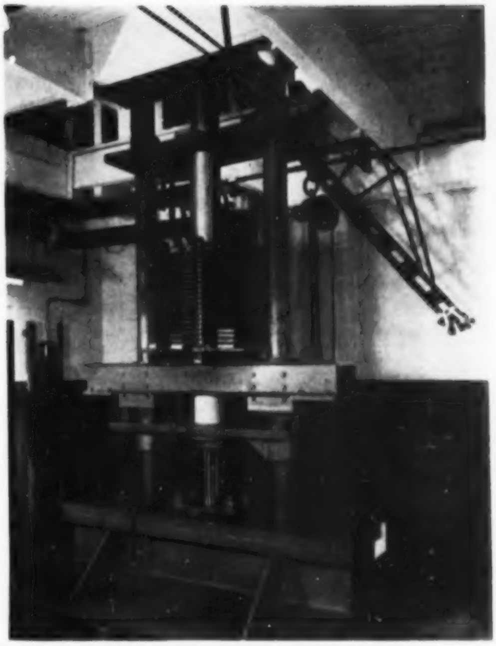


Fig. 9 – High-Pressure High-Temperature Unit for Forging and Hot Pressing of Large Pre-Consolidated Bodies of Beryllium Powder Without Atmospheric Protection

Fig. 10 – Internal Parts for Envelope Hot Pressing. At top is a packing tube used for alignment. Below is a group of six forms for long rods of triangular cross sections, leading to vacuum connection at right end

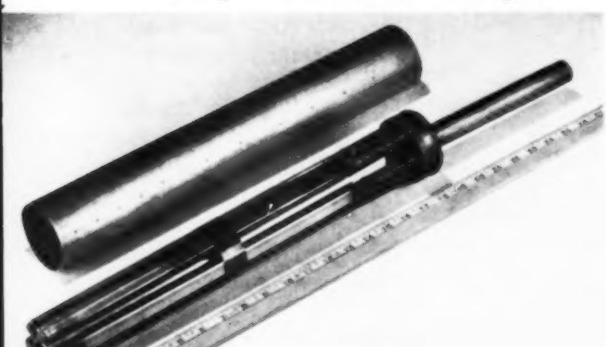
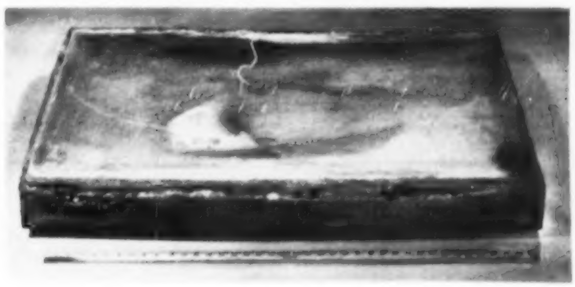


Fig. 11 – Large Vacuum Hot Pressed Block of Beryllium After Chemical Cleaning, the Usual Commercial Form for Further Fabrication



Book Review

A Basic Treatment of Casting Problems

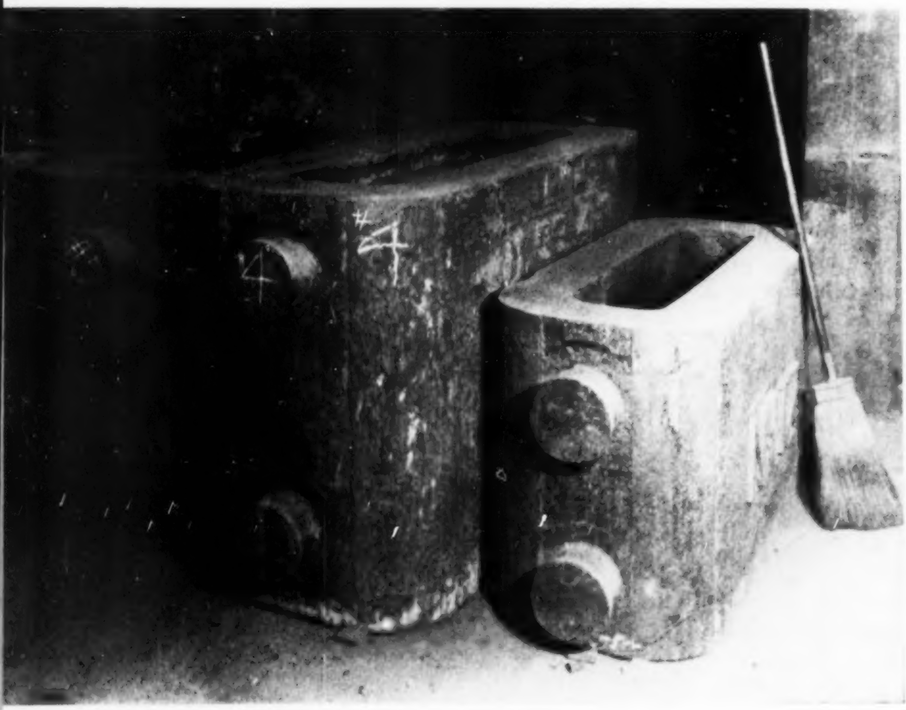
Reviewed by HAROLD J. ROAST*

THE CASTING OF NONFERROUS INGOTS, by Leslie Aitchison and Voya Kondic. 370 p., 71 illustrations. MacDonald and Evans, Ltd., London. Price 42 s. ($5.90).

THIS BOOK, which is confined to the topic of ingots, is nevertheless interesting to the present reviewer, a foundryman – especially its chapter on "Wrought Metals, Past and Present", containing comparisons between cast and wrought metals. It is one of the most cogent presentations of facts which are to be considered by makers of ordinary castings. Only as the foundryman appreciates the need for the utmost care to produce castings of the highest possible integrity can his product hope to remain a competitor of wrought metal. The fact, as brought out clearly by the authors, that ofttimes metal parts can *only* be made by ordinary casting methods throws upon the founder the responsibility for applying all the theory and practice obtainable so that the world's needs may be satisfactorily met. The authors clearly state at the outset that they make no attempt to include general foundry practice, and so are free to concentrate on the problems and theories underlying the production of nonferrous ingots – castings of simple shapes but of greatly varying size. However, it is evident that the techniques for melting metal are common to both ingots and castings, and consequently the information supplied in this connection is of equal interest to the general foundryman and to the ingot maker.

Those who expect to find definite directions in detail as to ingots of some specific composition will be disappointed. On the other hand, they will find a careful and detailed discussion of the principles underlying the production of *all* metal ingots. To quote from the authors' text: "The discussion revolves around the basic treatment of casting problems, and is designed more to illuminate it than to impart technological knowledge."

The reason given in the preface for the absence of numerous bibliographical references is interesting. Substantially it is that "Papa knows best". Readers are asked to believe that the authors have consulted the appropriate literature and to accept the authors' summary or conclusions as comprehensive and valid. This is truly an unconventional attitude for a technical author to take – even if it is the more-or-less instinctive attitude of most readers of technical works. The specialist or the intent student, however, should have some guidance into



One-Piece Cake Molds for Copper Casting. (Courtesy American Brass Co.)

*Mr. Roast is a bronze foundry consultant and a consulting editor for *Metal Progress*. He was long metallurgist and vice-president, Canadian Bronze Co., Ltd.

the most important literature, if only to help him appraise the coverage of the text he is studying. In this particular instance the coverage may be doubted, for the authors say they believe that their treatment on "ingot making" has not previously been attempted in the English language – a statement which neglects the excellent book "Casting of Brass and Bronze" by Daniel R. Hull, describing American ingot practice in detail and published in 1950.

Stress is laid on the greater importance of all the characteristics of ingots to be used for the manufacture of wrought products, as compared with ingots that are remelted before use, particularly in regard to such items as crystal size and, associated with it, pouring temperature. The ingot must be adjusted in every respect to the needs of the final product. The portions discussing the transition from liquid to solid state and its associated phenomena of volume change, solubility changes, macrosegregation and microsegregation are comprehensive, although this reviewer has a feeling that they are often couched needlessly in physico-metallurgical jargon. On the other hand, the considerable attention that has been given lately to such matters as turbulence, gas in metal, reaction of metal and the mold is reflected in the very careful dissertation covering these features.

This book will be given a definite place in the library of all who are scientifically interested in metal, as well as many of those whose interest is more prosaic. The arguments put forward are clear, logical, and convincing.

Critical Point

(Editorial)

Lodestones and Magnets

EVER NOTICE how few are the people, including engineers, who can resist the temptation to toy with a couple of small magnets? They are most mysterious things; almost as much so today as when the first lodestone was found by some prehistoric rock hunter. The mystified ancient probably thought there was some imprisoned spirit in it. The 20th century savant – much more sophisticated but only slightly less mystified – sustitutes "magnetic domains" for "imprisoned spirit".

Regardless of the terms used to define the property, the attraction this strange material still holds for people is very real, as was quite evident during a recent press tour the Carboloy Department of General Electric Co. conducted at its plant in Edmore, Mich. Here permanent magnets are produced in a great variety of sizes and shapes.

The fact that this magnetic behavior can be accounted for and predicted, in part at least, does not detract from the fascination it engenders. It's still quite wondrous that two pieces of metal can attract each other. Come to think of it, this deviation from the regular behavior of other metals gives some outward indication of the equally wondrous energies locked in the invisible structure of all metals. According to the present scientific model, one of the electron shells within each of the atoms of the three ferromagnetic metals (iron, nickel and cobalt) has certain unique characteristics which impart to the atom, or "domains" consisting of fairly large packets of atoms, the ability to act as tiny magnets. When these domains can be made to line up and stay lined up, the metal is a permanent magnet; when they point in random directions, the piece is demagnetized.

Now, even after talking with Carboloy's men and refreshing his memory with readings on the subject, this observer is as mystified as ever; the idea of a small magnet substituted for the mystery of a large magnet does not explain much. Although this supposed explanation – like the situation where a mirror reflects the image of another mirror which comes from still another – does not come very close to the essence of the thing, the domain concept (and some others) explains some of the nonconforming behavior of alloys compounded from nonmagnetic metals.

Examples where the synthesis of nonmagnetic metals produces an alloy with a strong magnetic property that is lacking in its constituents are the Heussler alloys of copper, manganese and aluminum, and "Silmanal" alloy of silver, manganese and alumiaum. Even more important, it has pointed the way to the development of extraordinary magnetic alloys from magnetic metals; and to simplifications in their commercial production in quantity.

Reduced to its most rudimentary essentials,

magnet manufacturing involves but two factors – composition and heat treatment. Compositions depend on three ferromagnetic metals, nickel, cobalt and iron, whose alloys also are ferromagnetic. Most modern alloys are of the precipitation hardening type; apparently magnetic "hardness" or permanence is similar to physical hardness or permanence in that the domains are fixed in position or directionality. (It is recognized that this simile is quite defective.) In fact, the principle of the production of these permanent magnets is to obtain by alloying and heat treatment a finely divided precipitate throughout the matrix which "keys" the oriented structure, and furnishes great resistance to change in magnetic condition, a property that is measured by the coercive force.

Cast magnets comprise nine tenths of the production at the Edmore plant of Carboloy Division, those made by powder metallurgy the remainder. The principal applications for the cast magnets are in television, radar and loud speakers; the magnets made by powder metallurgy are used in small electronic instruments. Most of the production at the present time is devoted to "Alnico 5", which contains 8% aluminum, 14% nickel, 24% cobalt, 3% copper and about 50% iron. This type, capable of lifting about 120 times its own weight, is the strongest commercial permanent magnet alloy known.

The magnets that are made by casting must be rough-ground to size. If the magnets are to be heat treated in furnaces, they are then loaded on small trays. (Induction heat is used for thin-walled ring magnets after they are strung on a quartz rod.) It is essential that all magnets in the tray are lined up in one direction so that, after heating above their Curie point (around 1650° F.), the subsequent cooling in a strong magnetic field will produce uniformly oriented specimens – that is, all pointing in one direction. The directionalizing equipment, most of which consists of solenoids, water-cooled, produces magnetic flux lines in the direction of the long axis. Approximately 2000 ampere-turns per inch are needed to produce the required field strength.

The solution treatment formerly used (2370° F. for 90 min.), which preceded the directionalizing treatment, has been eliminated by adding about 0.30% zirconium to the Alnico composition. Its function is to slow the rate of precipitation hardening. Final heat treatment is aging for 5 hr. at 1100° F. This allows any precipitated particles or nuclei formed in the preceding heat treatment to grow to the correct size for a metallurgical structure of maximum magnetic properties. J. P.

Nominating Committees for A.S.M. National Officers

In accordance with the Constitution of the American Society for Metals, President James B. Austin has selected a nominating committee for the nomination of president (for one year), vice-president (for one year), and two trustees (for two years each). This committee was selected by President Austin from the list of candidates submitted by the chapters. The personnel is:

Chairman: M. J. Day (Chicago Chapter), Armour Research Foundation, Technology Center, Chicago 16, Ill.

Ardrey M. Bounds (Philadelphia Chapter), Superior Tube Co., Norristown, Pa.

E. E. Stansbury (Oak Ridge Chapter), University of Tennessee, Knoxville 16, Tenn.

S. F. Urban (Buffalo Chapter), Director of Research, Titanium Alloy Mfg. Co., Hyde Park Blvd., Niagara Falls, N.Y.

W. E. Bancroft (Hartford Chapter), Chief Metallurgist, Pratt & Whitney Division, Niles Bemont Pond Co., West Hartford, Conn.

E. S. Rowland (Canton-Massillon Chapter), Chief Metallurgical Engineer, The Timken Roller Bearing Co., Canton 6, Ohio.

Eldon Van Meter (Wichita Chapter), Field Representative, Turco Products, Inc. (Home Address: 155 South Chautauqua, Wichita, Kan.).

C. B. Carpenter (Rocky Mountain Chapter), Head of Metallurgical Department, Colorado School of Mines, 1809 Ford St., Golden, Colo.

J. C. Thompson (San Diego Chapter), Metallurgist, Naval Electronic Laboratory, Naval Air Station. (Home Address: 4273 Menlo Ave., San Diego 5, Calif.).

Also in accordance with revisions of the constitution adopted in October 1944, a committee for the nomination of secretary (for two years) has also been appointed, consisting of the president of the society as chairman and the six immediate living past presidents. Personnel of this committee is as follows: James B. Austin *Chairman;* Ralph L. Wilson, John Chipman, Walter E. Jominy, Arthur E. Focke, Harold K. Work and Francis B. Foley.

These two committees will meet during the third full week in the month of May. They will welcome suggestions for candidates in accordance with the ⊕ Constitution, Article IX, Section 1 (b), which provides that endorsements of a local executive committee shall be confined to members of its local chapter, but individuals of a chapter may suggest to the nominating committee any candidates they would like to have in office. Endorsements may be sent in writing to either chairman or any member of either committee.

Amendments to the Atomic Energy Act*

SINCE 1946, when the Atomic Energy Act was written, there has been great progress in nuclear science and technology. The anticipations of 1946 have been far outdistanced. Our monopoly disappeared in 1949, but to counterbalance that debit a wide variety of atomic weapons — considered in 1946 to be mere possibilities — have today achieved conventional status. The thermonuclear weapon today dwarfs all. The launching of the U.S.S. Nautilus made certain the use of atomic energy for ship propulsion. Economic industrial power is in sight.

Obviously, many statutory restrictions based on actual facts of 1946 are inconsistent with the realities of 1954, and impede the exploitation of nuclear energy for the benefit of the American people and our friends throughout the free world. I, therefore, recommend that the Congress approve a number of amendments [to the Act] which would accomplish:

Widened Cooperation — Under present law we cannot give friendly allies the tactical information essential for their participation in military operations for their own defense and our own security. I urge, therefore, that authority be provided to exchange such information essential to the training of personnel for atomic warfare.

In the development of peaceful uses for atomic energy, additional amendments are required for effective United States cooperation with friendly nations. Such cooperation requires the exchange of certain "restricted data" on the industrial applications of atomic energy and also the release of fissionable materials in amounts adequate for industrial and research use. The Act should be amended to authorize such cooperation.

Present law prevents United States citizens or corporations from engaging in the production of fissionable material outside the United States. The President should be enabled to authorize the Atomic Energy Commission to determine whether such proposed activity adversely affects our security.

All of these proposed amendments should make it clear that the authority granted must be exercised only in accordance with conditions prescribed by the President to protect the common defense and security.

Protection of Information — The present act does not recognize degrees of sensitivity of "restricted data". The same clearance requirements apply to unskilled construction laborer and to scientist, which leads to many costly background investigations, and tends to impede and discourage desired participation with industry. Another security clearance problem relates to desirable communications between personnel of the Department of Defense agencies and the personnel of contractors with those agencies, even though the "restricted data" are protected by Department of Defense security regulations.

A large body of "restricted data" under present law relates primarily to military utilization of atomic weapons. The responsibility for the control of much of this logically should rest with the Department of Defense, where it can be adequately safeguarded under the Espionage Act and other applicable law.

I recommend, therefore, that the statutory definition of "restricted data" be amended to exclude information concerning the utilization of atomic weapons, as distinguished from information on their theory, design and manufacture.

There is also information which concerns primarily the utilization of weapons but which pertains also to their design and manufacture. In order to avoid difficulties in this marginal zone, I recommend legislation which also would authorize removal of such information from the "restricted data" category. This would be done only when the Atomic Energy Commission and the Department of Defense jointly determine that it relates primarily to military utilization of atomic weapons, and that it can be adequately safeguarded as classified defense information under the Espionage Act and other applicable law.

Peacetime Uses — The Federal Government can pioneer in the harnessing of atomic power. But, in this undertaking, the enterprise, initiative and competitive spirit of individuals and groups within our free economy are needed to assure the greatest efficiency and progress at the least cost to the public. Industry's interest in this field is already evident. There are indications that private corporations would increase their efforts significantly if the way were open for private investment in power reactors.

In amending the law to permit such investment, care must be taken to encourage the development in a manner as nearly normal as possible, and the program so proceed that this new industry will develop self-reliance and self-sufficiency.

To this end, I recommend amendments to the Atomic Energy Act which would:

Relax restrictions on ownership of fissionable materials.

Permit private ownership of reactors.

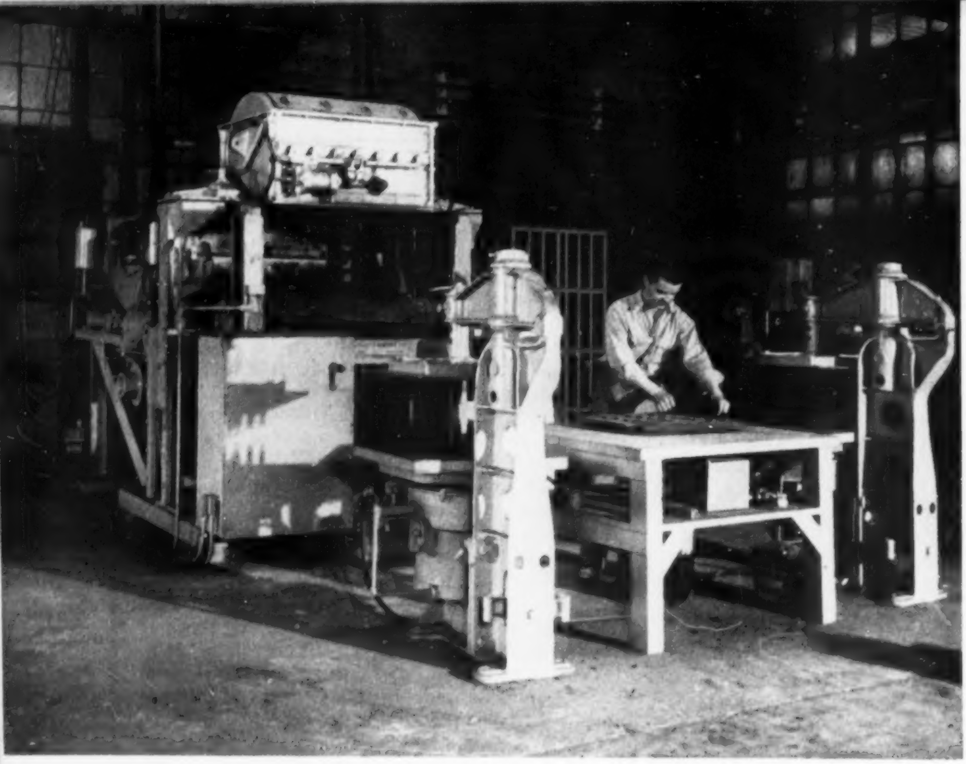
Establish minimum safety and security regulations.

Permit the Commission to sell materials and services to licensees.

Expand the area open to private patents to include the production as well as the utilization of fissionable material. Some mechanism must assure that Government contractors cannot build a patent monopoly.

The destiny of all nations during the 20th Century will turn in large measure upon the nature and the pace of atomic energy development here and abroad. The revisions to the Atomic Energy Act herein recommended will help make it possible for American atomic energy development, public and private, to play a full and effective part in leading mankind into a new era of progress and peace.

*Verbatim excerpts from President Eisenhower's message to the Congress, Feb. 18, 1954.



Casting Stainless Steel in Shell Molds

By H. J. COOPER
Executive Vice-President
and M. L. KATZ
Shell Mold Engineer
The Cooper Alloy Foundry Co.
Hillside, N. J.

In December 1951, *Business Week* reported: "All over the country, foundries are secretive about their shell molding operations. The fouled-up patent situation is responsible for slowing up development of the process by curbing the usual swapping of technical information." In June 1952, the Cooper Alloy Foundry Co. took the lid off the secrecy that had been shrouding shell mold developments by telling the step-by-step story of laboratory and production developments. A brief glimpse at the picture today shows an ever-growing fund of technical data and a more honest exchange of findings. It is our intention here to review the shell molding of stainless steel and to explain to the best of our ability just where the art stands.

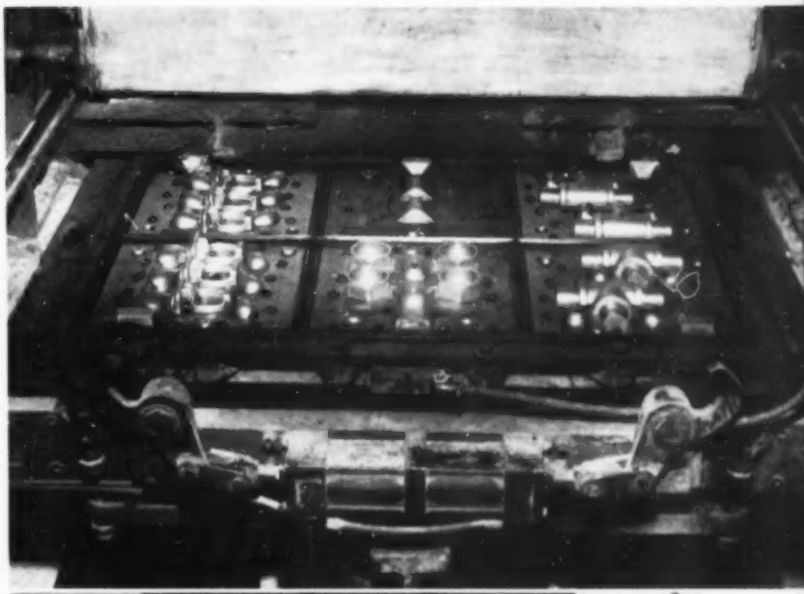
Basically, the shell mold process utilizes the thermosetting properties of phenolic or urea resins to provide a bond for silica or zircon sand in the construction of a mold. It is probably true that every foundry uses its own "secret" blend, but in our experience with high alloys, a mixture of 87% sand (160 A.F.S. fineness), 8% resin and 5% iron oxide or zircon flour is the most economical for consistent results.

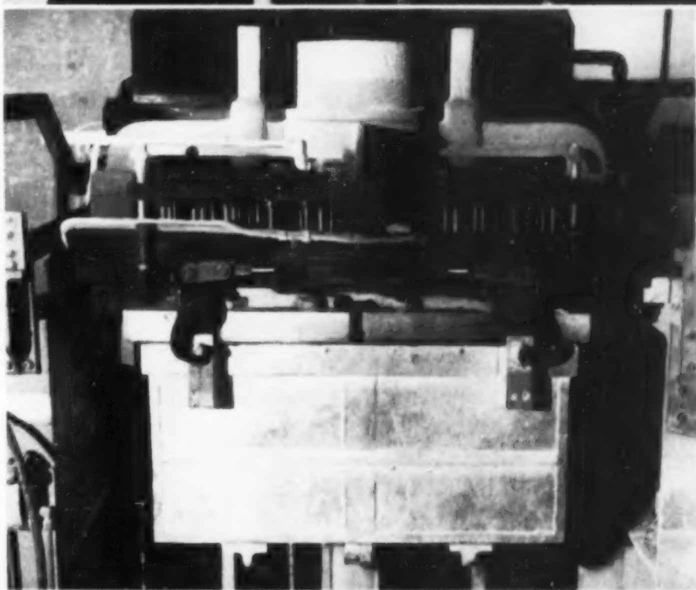
MECHANICS OF THE PROCESS

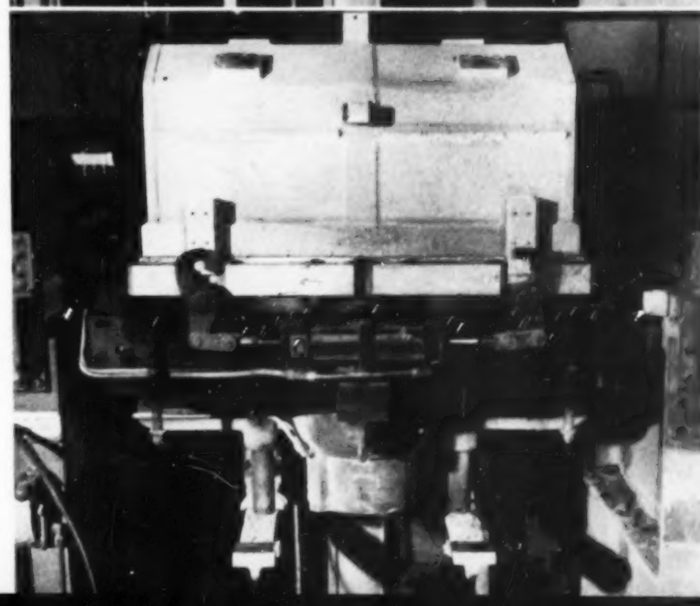
The major difference between shell molding and conventional sand molding is the method of manufacturing the molds. The production of shell molds is essentially a mechanical opera-

▸ ▸ ▸ ▸ ▸ ▸ ▸ ▸

Fig. 1 – (Opposite Page) – Shell Mold Division at Cooper Alloy Foundry Co. Machine Shown Is Original Production Unit. Fig. 2 (At Right) – Pattern Plate Mounted in Position, Heated to 500° F. Fig. 3 (Center) – Pattern Rotated, Dump Box Raised and Clamped in Position. Fig. 4 (Bottom of Page) – Unit Rolled Over to Coat the Pattern







tion. Here is a step-by-step picture of just what happens, as illustrated in Fig. 1 through 7.

1. The pattern plate is mounted in the machine shown in Fig. 1.
2. The pattern plate is preheated to 500° F. and maintained at this temperature (Fig. 2).
3. The hopper is filled with the sand-resin mix.
4. The pattern rotates and the dump box comes up and clamps in position (Fig. 3).
5. Pattern and box roll over to coat the pattern (Fig. 4).
6. The complete unit is rolled back, returning excess sand mix to the hopper.
7. Dump box is lowered and the pattern with its soft shell is returned to normal position (Fig. 5).
8. The oven rides out over the mold for curing.
9. Oven retracts.
10. The ejector pins raised the hardened mold from the pattern (Fig. 6).
11. The mold (Fig. 7) is removed manually from the machine.

Steps No. 1 and 11 are manual operations; all steps in between are completely automatic, with total cycle averaging just about 2 min. for one to three molds per cycle, depending on shell size.

THE ART OF SHELL MOLDING

So much for the mechanical side. Let us now take a closer look at the "art". To begin with, patternmaking takes on a new significance. Although

the value of accurate patterns cannot be overemphasized in conventional sand molding, shell molding poses new problems of perfection, design and strength. Although cast iron plates have been used, for our operations where production runs are relatively small, excellent results are achieved with aluminum plates ¾ to 3 in. thick, on which aluminum patterns and gates are mounted. To get maximum dimensional accuracy, patterns must be prepared with the accuracy demanded of toolmakers, and their high cost is one of the major reasons for limiting shell molding to production items. This is one place where skill and proper judgment can easily spell the difference between success and failure.

The shell molding industry is now fast acquiring "specialists", and for the manufacturer just getting his feet wet in shell molding, it is highly recommended that patterns be ordered from those with specific experience in preparing shell mold patterns for the metal that is to be cast.

Patternmakers have been much more fortunate than coremakers in adapting to the new demand. Shell core techniques are still in their infancy and, in the high-alloy field, standard oil-bonded sand cores are still being used for production runs. This is one field where research must continue, and it is hoped that by the constant interchange of technical information we may be able to lick this problem before the end of 1954.

Another phase where casting "art" plays an important part is in closing the mold. A variety of methods have been adopted:

1. Clamping the outside edges with spring wire.

2. Sealing by means of a cold or hot setting paste.

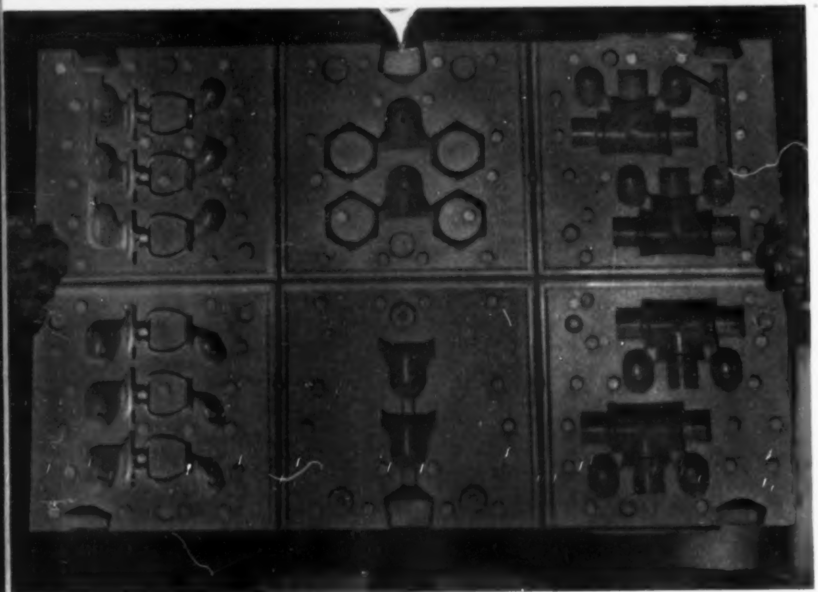


Fig. 5 (Top of Page) – Unit Rotated Back to Normal Position. Pattern with soft shell, awaits the oven. Fig. 6 (Center) – Oven Retracts and Ejection Pins Raise Cured Shell Mold. Fig. 7 (Lower Left) – Close-Up of Mold, Showing Valve Bonnets (Left), Union Nuts (Center), Tee Fittings (Right)

3. Sealing by means of a special binding tape.
4. Bolting the molds together.
5. Bonding with resin.
6. Mechanical clamping in fixtures, boxes, or other devices.

In our shop we favor the second method. We use a cold setting paste but speed up the action by applying it to a hot shell.

Back-up is another important phase of the art which is still experimental. Steel shot, gravel, sand and other materials have been tried. It is our feeling that the use of back-up materials injects a materials-handling problem which offsets much of the advantage to be gained from the simplicity and cleanliness of shell molding. To date, we have successfully cast 30 lb. of metal in a single pasted mold without back-up, and up to 150 lb. of metal in bolted molds. Since back-up materials do not seem to have any effect on quality, and since they complicate the process, the future should see continued development along the lines of casting without resorting to back-up.

Metallurgical Considerations – It has been claimed that shell molds are chilling in effect, and induce finer grain size and high skin soundness. To the best of our knowledge, this has not been substantiated. Studies performed at the Material Laboratory of the New York Naval Shipyard have shown that shells as thin as 1/16 in. consistently yield coarser-grained specimens than produced in green sand; this indicates a positive insulating effect. Additional tests conducted by various investigators have also indicated that back-up material exerts little influence on chilling rates. While these studies were performed principally on bronze and aluminum test specimens, the stainless steels are similarly affected.

Further tests at the Navy Yard on nonferrous alloys indicate that shell cast test bars show slightly higher tensile strength and ductility and slightly lower yield strength. Our experience with stainless steel at Cooper Alloy indicates very little difference, if any. The whole foundry art has advanced to such an extent that most foundries can be relied upon to turn out sound castings in sand molds, metal molds, or any other kind of mold.

Dimensional Accuracy – Shell molding may be considered one of the "precision" casting processes. Generally it is thought of as midway between lost wax methods and conventional sand casting in this respect. When we take into consideration, however, the larger sizes made by shell molding, it is not unwise to consider that the lost wax method could guarantee no better tolerances than are now being achieved by shell molding. An important point to remember in contrasting sand and shell castings is that shell molds cure on the pattern, and pattern dimensions are held very close. As a result the process guarantees a high degree of uniformity, as well as dimensional accuracy and reproducibility.

ADVANTAGES OF SHELL MOLDING

Let us now go back and see whether the advantages anticipated while the process was still in its experimental stages have proved to be valid, and determine just how far the process has come with respect to stainless steel.

Basically, these advantages may be listed as follows:

1. Automatic handling methods.
2. High production speeds.
3. Low reject rate.
4. Superior surface finish.
5. Low machining costs.
6. Dimensional accuracy.
7. High yield.
8. Greater storage capacity.
9. High output per unit of floor area.
10. Clean working conditions.

With respect to automatic handling, there is no doubt that shell molding is living up to early expectations. A number of machine manufacturers have developed a wide variety of automatic and semi-automatic moldmaking units. In our shop, we are currently using two different types, both of which are push-button controlled from the time the pattern is in place to the time the half-shells are ejected.

Automatic operation naturally leads to higher production speeds. Each of the machines at Cooper Alloy is capable of producing better than 400 molds on an 8-hr. shift, as compared to about 75 for the normal squeeze-line production of common green sand molds.

With respect to lower rejection rate, there are pros and cons. In the production of stainless steel valves and fittings at Cooper Alloy (rather small parts in high production), we have definitely put a dent in the rejection rate. The smooth shell mold offers less resistance to the flow of metal and thus gives sound castings in much thinner sections. It has been estimated that for the same metal thickness, the length of travel which can be tolerated in shell molds is practically double that permissible in sand molds. Also some parts which could not eco-

Fig. 8 – Storage of Shell Molds (Like Egg Cartons) Is a Simple Matter, and Takes Little Floor Space

nomically be cast in sand can be made by the shell molding process.

On the other hand, since the shell process is still more or less experimental, each new part requires an individual rigging study, and this has resulted in a great deal of rejected material. Over the long run, however, it seems fairly obvious that shell molding will result in lower rejection rates, provided the limitations of the process for certain parts are kept in mind.

Advantage 4, superior surface finish (and its corollary, greater legibility of identification marks) is obvious. When properly made, the surface finish is midway between that of sand and investment castings. Identification marks are clear and the surface appearance is generally uniform and clean.

This brings us naturally to lower machining costs and superior dimensional accuracy. Our experience with stainless castings indicates that although tolerances can sometimes be held within ±0.002 in. per in., a figure of ±0.005 in. per in. is a more accurate and realistic guide. This is certainly better than can be expected from sand castings, and approaches the results achieved by investment casting.

Higher yield (item 7) results from the superior flow and solidification characteristics of the smooth shell; smaller gates and risers can be used, and more of the poured metal can go into the casting rather than to feeders and vents.

The greater storage capacity is illustrated in Fig. 8. The resin-bonded shell molds are hard and relatively durable. They can be stored for unlimited lengths of time without absorbing moisture. Their light weight and thin dimensions make them ideal for storing in specially designed racks that take a minimum of floor space.

Advantages 9 and 10, high output per unit of floor space and cleaner working conditions, are both inherent in the nature of the process. The area required for the manufacture of molds, the storage area, and the pour-off area, are all less than required by sand molds. Working conditions are better because, for the most part, there is less manual work, less noise, and, of course, less sand.

From our experience we think it can be said without fear of contradiction that the basic advantages listed above have definitely proved to be real, and that in the production of shell molds for mass casting, these advantages can be realized to a great extent.

FUTURE GROWTH

The growth of the shell process is inevitable because it serves the selfish advantage of all concerned. Once the production bugs have been ironed out, the foundry gains because it can look for these advantages, singly or in combination: faster production, higher yield, less work area, cleaner work conditions. The customer gains because he gets a better-looking product with clearer identification and closer tolerances (requiring less machining), and he can get it faster. Shell molding may also be used to produce parts which could not be cast economically by any other method.

Since by its very nature the shell mold process is likely to reshape a good part of the foundry industry, metal engineers, product designers, foundrymen, and metal-conscious executives would do well to keep their eyes on the process and encourage the continual exchange of technical information.

Wire Hardness Test

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THE TEST for tensile strength is the most informative and useful one of the various mechanical tests for wire. It is reliable and has the decided advantage, not common to other tests, of giving reproducible results because the tensile determinations are not materially affected by different types of testing equipment or by different operators. The Rockwell hardness test, on the other hand, has not been recommended for round wire unless the specimen is ground with parallel sides, and unless it is confined to wire of such diameters that no bulging of the specimen occurs under test. Consequently, for round wire the test for tensile strength has been greatly preferred to the one for Rockwell hardness. However, the latter is not only of definite value and utility, but is a standard test for flat wire. It is also of useful application to heat treated round wire in diameters 0.100 in. and larger.

This article describes a new hardness test, one that is simple, accurate and can be used with all available machines for Rockwell hardness testing. It can be used on wire ranging from 0.005 to 0.125 in. diameter for the measurement of hardnesses varying from that of dead soft aluminum to tungsten carbide. Because of trademark restrictions, the authors will call this the Wedge test, the procedure for which is exactly the same as for the Rockwell test. The shape of the wedge diamond indenters is shown in Fig. 1, together with the shape of their impressions for both minor and major loads in 0.060-in. wire. The area of the impress is practically an ellipse, of which the ratio of minor and major axis varies for both the diameter of the wire and the depth of penetration. This is in contrast to the Brinell and Rockwell impressions which are circular and to the Vickers which is square. Wedge readings will be abbreviated as W-60, meaning a 60-kg. load, with a wedge-shaped diamond having an included angle of 120° and an 0.008-in. radius. This was the standard adopted after the extensive tests to be described.

The hardness testing of thin wire can be done with a Service diamond hardness tester (Fig. 2), or the Clark or Wilson Rockwell machines, provided these are fitted with the special adapters shown in Fig. 3. These adapters consist of: (A) a clamp to hold the wire on a special "V" anvil by means of hold-down clips; (B) a locating finger attached to the penetrator thumbscrew for the alignment of wire and wedge; (C) the anvil body which, by means of a tapered head and a two-piece threaded nut, fastens tightly to the elevating screw so as to eliminate the turning of the anvil relative to the wedge.

The disagreement in the results of various investigations of hardness testing on round wire

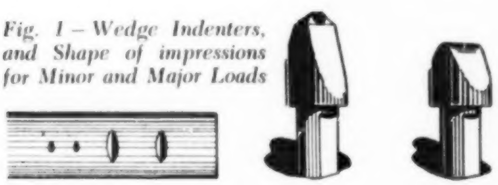


Fig. 1 – Wedge Indenters, and Shape of impressions for Minor and Major Loads

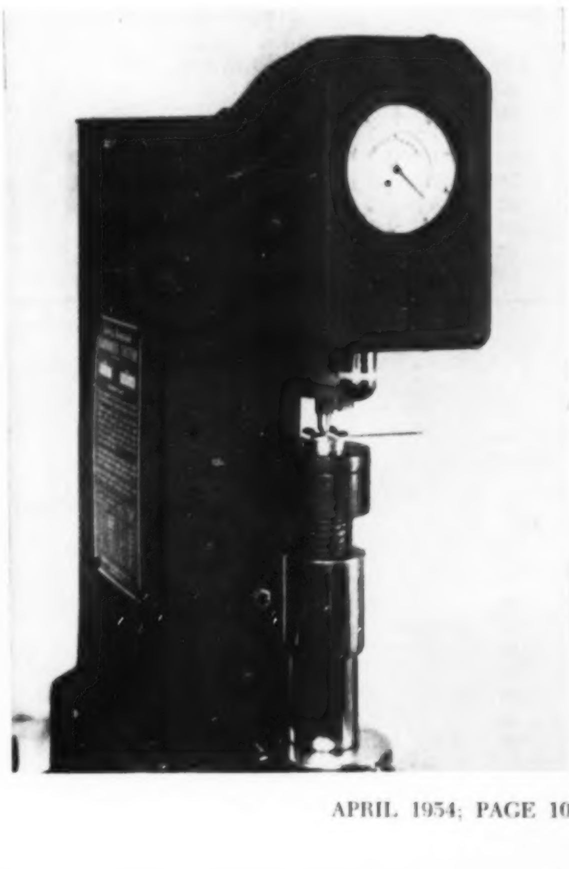


Fig. 2 – Service Diamond Hardness Machine With Adapters for Testing Round Wires

Testing Fine, Round Wire

becomes very pronounced as the diameter becomes smaller than ¼ in. These differences in results are caused by limitations in the design and construction of available machines for Rockwell testing, and may be ascribed to any one of the following causes:

1. Misalignment of the wire being tested in relation to the penetrator because the lead screw is not perfectly centered, or the "V" groove in the anvil is not properly ground.
2. Improper combination of anvil and holding fixture.
3. Incorrect scale used in checking the very small rounds.
4. Sample has poor surface finish or the cylinder is not perfectly round.
5. Floating spindle of one sort or another used in the Rockwell machines of Clark, Service Diamond, and Wilson types causes the penetrator to slide off the top of small rounds since the spindle is not restrained to a fixed position.

Fig. 3 – Parts of Adapter Which Permits Use of Standard Hardness Machine for Wire Hardness Tests. Parts include clamp (A) to hold the wire on a special "V" anvil, locating finger (B) on penetrator thumbscrew for aligning wire and wedge, anvil body (C), fastened by means of a tapered head and a two-piece threaded nut to the elevating screw to prevent rotation of the anvil relative to the wedge

Table I – Round Work Correction

Rockwell Diamond Penetrator													
Add to Reading on C, A, D Scales							Add to Reading on 15N, 30N, 45N Scales						
Dial Reading	Wire Diameter, In. ¼	⅜	½	⅝	¾	1	Dial Reading	Wire Diameter, In. ¼	⅜	½	⅝	¾	1
100	0.0	0.0	0.0	0.0	0.0	0.0	100	0.0	0.0	0.0	0.0	0.0	0.0
90	0.3	0.2	0.2	0.2	0.1	0.1	90	0.3	0.2	0.2	0.1	0.0	0.0
80	0.7	0.5	0.4	0.3	0.2	0.2	80	0.6	0.4	0.3	0.2	0.1	0.1
70	1.2	0.8	0.6	0.5	0.4	0.3	70	0.9	0.6	0.5	0.4	0.3	0.2
60	1.7	1.1	0.9	0.7	0.6	0.4	60	1.3	0.9	0.7	0.6	0.4	0.4
50	2.3	1.6	1.2	1.0	0.8	0.6	50	1.7	1.2	0.9	0.8	0.6	0.5
40	3.0	2.2	1.6	1.3	1.1	0.8	40	2.3	1.6	1.2	1.0	0.8	0.6
30	4.0	2.9	2.2	1.8	1.5	1.1	30	2.9	1.9	1.5	1.2	1.0	0.7
20	5.1	3.7	2.8	2.3	1.9	1.5	20	3.4	2.2	1.8	1.4	1.2	0.8
10	6.6	4.7	3.8	2.9	2.4	2.0							
Rockwell 1/16-In. Ball Penetrator													
Add to Reading on B, F, G Scales							Add to Reading on 15T, 30T, 45T Scales						
Dial Reading	Wire Diameter, In. ¼	⅜	½	⅝	¾	1	Dial Reading	Wire Diameter, In. ¼	⅜	½	⅝	¾	1
100	3.1	2.2	1.6	1.3	1.1	0.8	100	0.0	0.0	0.0	0.0	0.0	0.0
90	4.1	2.9	2.2	1.7	1.4	1.1	90	1.1	0.8	0.7	0.6	0.5	0.4
80	5.1	3.5	2.7	2.1	1.7	1.4	80	2.2	1.6	1.3	1.1	0.9	0.7
70	6.0	4.2	3.2	2.6	2.1	1.6	70	3.3	2.4	1.8	1.5	1.3	1.0
60	7.0	4.9	3.7	3.1	2.6	1.9	60	4.3	3.2	2.4	2.0	1.7	1.3
50	7.9	5.5	4.2	3.5	2.9	2.2	50	5.3	3.9	2.9	2.4	2.0	1.5
40	8.9	6.1	4.7	3.9	3.2	2.4	40	6.3	4.6	3.4	2.9	2.4	1.8
30	9.8	6.7	5.2	4.3	3.5	2.6	30	7.3	5.2	4.0	3.3	2.7	2.0
20	10.7	7.3	5.6	4.7	3.8	2.9	20	8.3	5.8	4.5	3.7	3.0	2.2
10	11.7	7.9	6.0	5.1	4.2	3.1	10	9.3	6.4	5.0	4.1	3.3	2.5
0	12.5	8.5	6.5	5.5	4.5	3.3	0	10.3	7.0	5.4	4.5	3.6	2.7

When the usual "V" anvil is used, it is difficult to align the indenter at right angles to the longitudinal axis of the wire, because of the float or clearance in the spindles and the float of the anvil in the elevating screw bushing of the standard machines. Figure 4 shows the effect of devi-

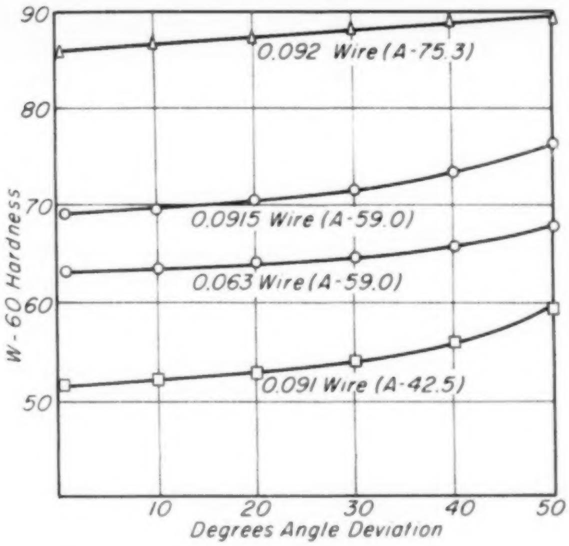


Fig. 4 – Effect of Deviation From 90° Crossed Axis on Wedge Hardness. (Values within parentheses are Rockwell hardness)

ation from 90° crossed axis on the Wedge hardness number; in general, a deviation error of 15° raises the reading by one point. Little time is lost or extra effort required for accurate production testing.

Since a normal Rockwell test is impossible on small-diameter wires, all Wedge readings are compared to Vickers values on the same wire. The Vickers values were then converted to Rockwell A by using A.S.T.M. Conversion Chart E 48-47. Since the Vickers readings were taken on a flat surface, all Wedge readings can be compared to Vickers readings without the necessity of calculating an extremely complex round work correction factor. The Rockwell A scale is also a 60-kg. Wedge test. Another reason for writing in terms of the Rockwell A scale is that this is the only scale that covers the entire range of hardnesses from soft aluminum to tungsten carbide. Special care was taken to get extremely accurate Vickers readings; these were obtained with a Kentron microhardness tester at various loads using a laboratory technique rather than production Vickers testing. The wire samples were lightly stoned to produce a flat approximately 0.030 in. wide. Wedge impressions were made close to the Vickers to eliminate errors due to variations in hardness over the length of the wire. Figure 5 shows the holding fixture, and Vickers and Wedge impressions for the major load.

All Wedge readings are reproducible and this method can be employed as widely on small-diameter work as can the Rockwell test on flat surfaces. A rather simple statistical analysis is presented in Table II for three 0.090-in. diameter steel wires of different hardness. The average value is the sum of the individual Wedge values divided by the number of readings. The residual, or deviation, for each reading is the difference between that reading and the average value. The average residual is then divided by the square root of the number of readings so as to obtain the probable error, as shown in the last line of Table II.

The maximum deviation was −1.35 for the softest wire. For the two harder wires, the maximum deviation was 0.6. Our method of computation defines the probable error as the deviation from the average within which 50% of the readings will fall. The error for Wedge readings is well within that for standard Rockwell readings on flat surfaces.

SELECTION OF WEDGE PENETRATORS

The actual choice of dimensions for the penetrator depends on the particular diameter and hardness value of the wire. The results of our

Fig. 5 – Holding Fixture With Wire Bearing Vickers (Center) and Wedge Impressions (Left)

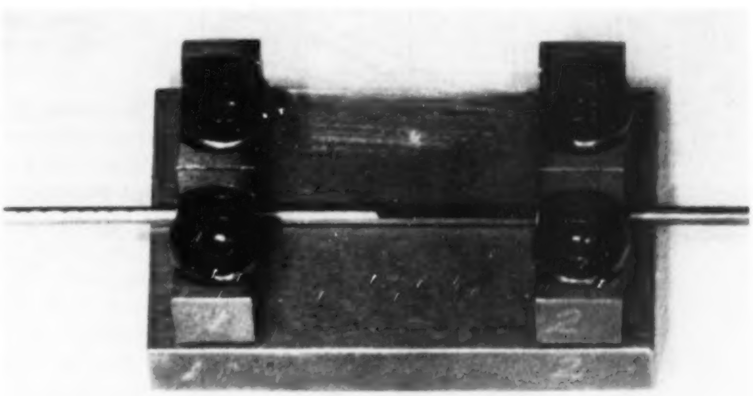


Table II – Statistical Analysis of Wedge Hardness Values for 0.90-In. Diameter Wire

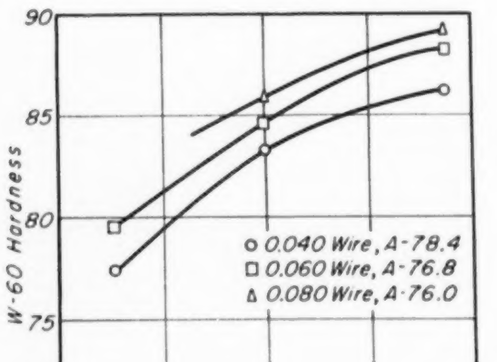
High Hardness		Medium Hardness		Low Hardness	
Wedge Reading	Residual	Wedge Reading	Residual	Wedge Reading	Residual
87.0	+0.5	68.0	+0.6	45.0	−1.35
86.5	0	67.8	+0.4	46.0	−0.35
86.5	0	67.0	−0.4	47.2	+0.85
86.4	−0.5	67.8	+0.4	47.2	+0.85
Average 86.5	Average 0.25	Average 67.4	Average 0.55	Average 46.35	Average 0.85
Probable error 0.12		Probable error 0.23		Probable error 0.42	

tests show that a diamond wedge having the same angle and radius as the standard Rockwell diamond penetrator (120°, 0.008 in.) and a carbide wedge of 60° angle and a 1/16-in. radius corresponding to the standard 1/16-in. Rockwell B ball penetrator, cover practically the same range of hardness in wires as the Rockwell penetrators do for flat pieces. A standard load of 60 kg. is used over the entire range of hardness.

In Fig. 6 wedge hardness versus radius is plotted for three diameters of wire of the same hardness, approximately Rockwell A-77. As expected, the smaller the radius of the chisel edge, the deeper the penetration and the lower the hardness reading.

The penetrator with the 0.002-in. radius offers the advantage of extending the scale to give greater differences in readings between hard and soft wires. However, on soft materials, it tends to cut or slice through the wire and the readings are very dependent on the speed and duration of load application. The 0.015-in. radius does not offer sufficient spread in readings for different hardnesses. The 0.008-in. was found to be a satisfactory compromise. It should be emphasized, however, that the Wedge test is just as flexible as the Rockwell test and the scale can be extended by using a 100 or 150-kg. load, which corresponds to the Rockwell D and C scales. For example, the equivalent of Rockwell A-75 to A-85 on the C scale is 49 to 67, or an increase of 8 graduations on the dial.

Fig. 6 – Wedge Hardness Plotted Against Radius for Three Diameters of Wire Shows That Deeper Penetration and Lower Hardness Values Result With Penetrator Having a Small Radius



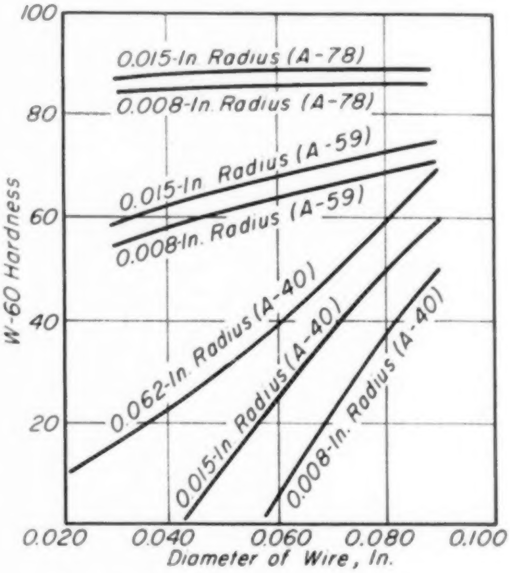


Fig. 7 – Comparison of Results for Indenters of 0.008 and 0.015-In. Radius With Rockwell Values (Converted From Vickers Readings) for Wires of Various Hardnesses (Rockwell Hardness Within Parentheses). Curve for 0.062-in. radius is from carbide indenter having a 60° inclined angle

Hardness results with 0.008 and 0.015-in. radius indenters are compared in Fig. 7. These show that for the range between Rockwell A-50 and A-75, the 0.008-in. radius is quite satisfactory. This is the normal hardness range where the Rockwell diamond penetrator is used. The smaller diameters of the soft wires (Rockwell A-40) fall outside the hardness scale. Since

Complexity of Conversion

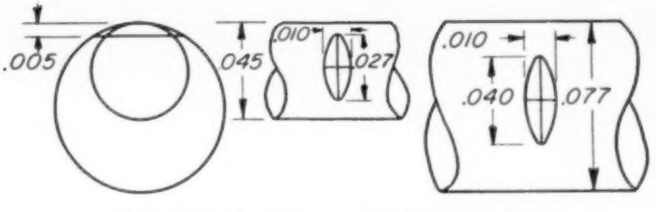


Fig. 8 – Wedge Penetrator Produces Geometrically Dissimilar Areas Because Length of Major Axis Is Influenced by Diameter of Wire Being Tested Even Though Rockwell Hardness Dial Readings Are Same for the Wires

this is the range where ball penetrators are used in ordinary Rockwell testing, an indenter is needed that is as different in penetration geometry from the 120° and 0.008-in. wedge, as the Rockwell B ball penetrator differs from the Rockwell C spheroconical diamond. On the basis of exeperimental data obtained on soft wires of small diameter, a carbide wedge of 60° included angle and radius of 0.062 in. was found to be most practical; one set of readings with this penetrator on a wire of Rockwell A-40 hardness is shown in Fig. 7. The sharp included angle of 60° permits the 0.062-in. wedge to act almost like a ⅛-in. diameter cylinder and practically corresponds to a crossed-axis cylinder penetration test.

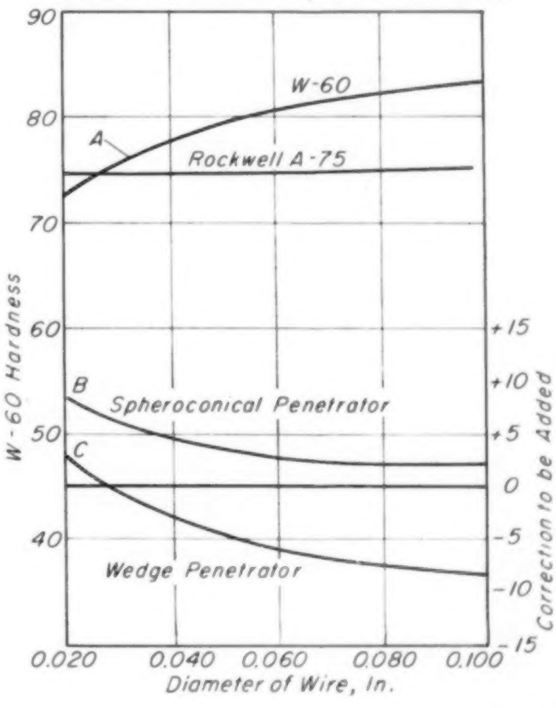
CONVERTING WEDGE TO ROCKWELL

The correction for a Wedge penetrator on round work is different from that for a spheroconical penetrator, even for the same 120° angle and 0.008-in. radius. This is because the penetration, which is what the Rockwell test measures, is not really the fundamental factor – hardness is actually determined by the *area* of the impression made by a definite load. When variation of depth of penetration produces geometrically similar projected impressions, as in the Vickers or Rockwell test on flat stock, then penetration can be converted to hardness. With the Wedge penetrator, variation in depth of penetration does not produce similar impressions. The lengths of the minor axis of the projected elliptical areas are similar for different diameter wires, but the major axis varies according to the wire diameter. This is because the length of the edge of the penetrator is considerably greater than the diameter of the wire. In the example shown in Fig. 8, the depth of penetration is 0.005 in., which corresponds to a dial reading of 57.5 for wires of 0.045 and 0.077-in. diameters. The projected elliptical area for the 0.045-in. wire is 0.00021 sq.in., the minor axis being 0.010 in. and the major axis 0.027 in. The projected area for the 0.077-in. wire is 0.00034 sq. in.; the minor axis is the same (0.010 in.) since the penetration is the same, but the major axis is 0.040 in. The Wedge area for the 0.077-in. wire is greater by a third and it is therefore only two-thirds as hard as the smaller wire – even though they both read 57.5 on the dial – since on the Vickers scale hardness is inversely proportional to area supporting the load.

If both wires were of the same hardness, the dial readings would be entirely different. Thus, when the smaller-diameter wire would give a reading of 57.5, the larger-diameter wire would be 68 on the dial. This example indicates the complexity of the problem.

Large corrections are needed for small wires, as can be seen from Fig. 9. The top curve shows

Fig. 9 – Curve A Shows How Hardness Varies With Diameter of Wire; Curve B Is Theoretical Correction for Spheroconical Penetrator in Comparison With Curve C for Wedge Penetrator Corrections for Wires of Same Diameters



Wedge Hardness Test for Wire

a W-60 reading of 83 for a wire of 0.080 in. diameter, and a W-60 reading of 73 for a wire of 0.020 in. diameter. Vickers tests on stoned flat areas on each wire show that both wires have an actual hardness of Rockwell A-75. The correction to be added to the Wedge reading for the 0.080-in. wire so as to convert it to this hardness is 75 minus 83 or −8 points. The correction is plotted on the lowest curve (Wedge penetrator on cylinder) as the negative distance from the zero correction ordinate. The correction to be added to the wedge readings on the 0.020-in. wire to convert it to the equivalent of Rockwell A-75 is 75 minus 73 or 2 points (shown on the lowest curve, Fig. 9).

For the sake of comparison, a correction curve for a spheroconical penetrator acting on an identical cylinder is also plotted in Fig. 9. An actual test is impossible on these diameters with a spheroconical penetrator, so the correction curve is purely an exercise in descriptive geometry and is based on equivalent projected areas being identical in hardness.

The curves in Fig. 9 illustrate two rather unusual facts. First, the correction for the 0.020-in. wire with a spheroconical penetrator is 9 points, which is extremely large. In geometrical terms, the correction is the change in shape of the impression from a circle to an ellipse as the diameter decreases from infinity for a flat surface. This means that the impression for the 0.020-in. wire has elongated considerably and is now almost of the same shape as a Wedge impression. Second, the correction for the Wedge penetrator is negative for diameters larger than 0.028 in. and positive for diameters smaller than 0.028 in. at this particular hardness.

Again using geometrical terms, this Wedge correction simply means that the elongation of the major elliptical axis relative to the minor axis decreases as the wire diameter becomes smaller. And so, while the impression area for wire larger than 0.028 in. is actually the same as a spheroconical impression would be, the depth of penetration is less because the length of the major axis is at the top of the wire where small depth differences give a large length of axis increase. This means that we subtract the correction from the Wedge reading to get the equivalent Rockwell A value for a flat surface. Below 0.028 in. diameter, we are closer to the middle of the circle and small depth differences give even smaller length of axis increase. We then approach spheroconical penetrator geometry and add the correction from the Wedge reading to get Rockwell A on a flat surface.

A correction chart for Wedge readings on round work is shown in Table III. However, it is not complete, and should not be used in practice, except as a guide.

In conclusion, we would like to point out that there is no way to compare with each other the hardnesses of any two cylinders and still use dial readings. In other words, a ¼-in. round giving a reading of 40 for a Rockwell C penetrator and weight is not 10 points harder than a ¼-in. round which gives a reading of 30. If a flat were ground on each round and hardness measured on the flats, the difference would be 9 points when the correction of 3 for the round work is added to the 40 reading and 4 is added to the 30 reading. Because this difference is small, and round work corrections are relatively new in Rockwell testing, this difference is very often neglected. With the Wedge test, this difference is much greater because of the smaller diameter of the wires, and also because the correction can be negative or positive. Therefore, the chart converts directly to a Rockwell A value for a flat surface and thereby prevents the user from attempting to compare the initial dial readings as differences in hardness.

Table III – Correction Values to Convert Wedge to Rockwell-A Hardnesses

Wedge Dial Reading	Rockwell A Hardness for Various Wire Diameters in In.								
	0.020	0.030	0.040	0.050	0.060	0.070	0.080	0.090	0.100
90	110	98	91	88	85	83	81	80	78
85	94	89	83	81	78.5	76.5	74	73	72
80	89	82	77	75	73	71	69	68	67
75	85	78.5	73.5	71	68	66	65	64	63
70	81	75	70	67	64	62	61	60	59
65	77.5	71.5	67.5	63.5	60	58	57	55	54
60	74	68	63	60	57	55	53	51	50
55	70.5	66	60	57	55.5	52	49	47	46
50	67	62	57	54	52	49	46	44	42
45	64.5	59.5	55	52	50	46.5	43	40	38
40	62	57	53	50	48	44	40	37	34
35	59.5	55	51.5	48.5	46	42	38	33	31
30	57	53	50	47	44	40	36	31	27
25	55.5	51	49	45.5	42.5	38	34	29	25
20	52	49	48	44	41	36	32	27	22
15	50	48	47.5	42.5	40.5	35	31	25.5	20
10	48	47	46	41	39	34	30	24	18

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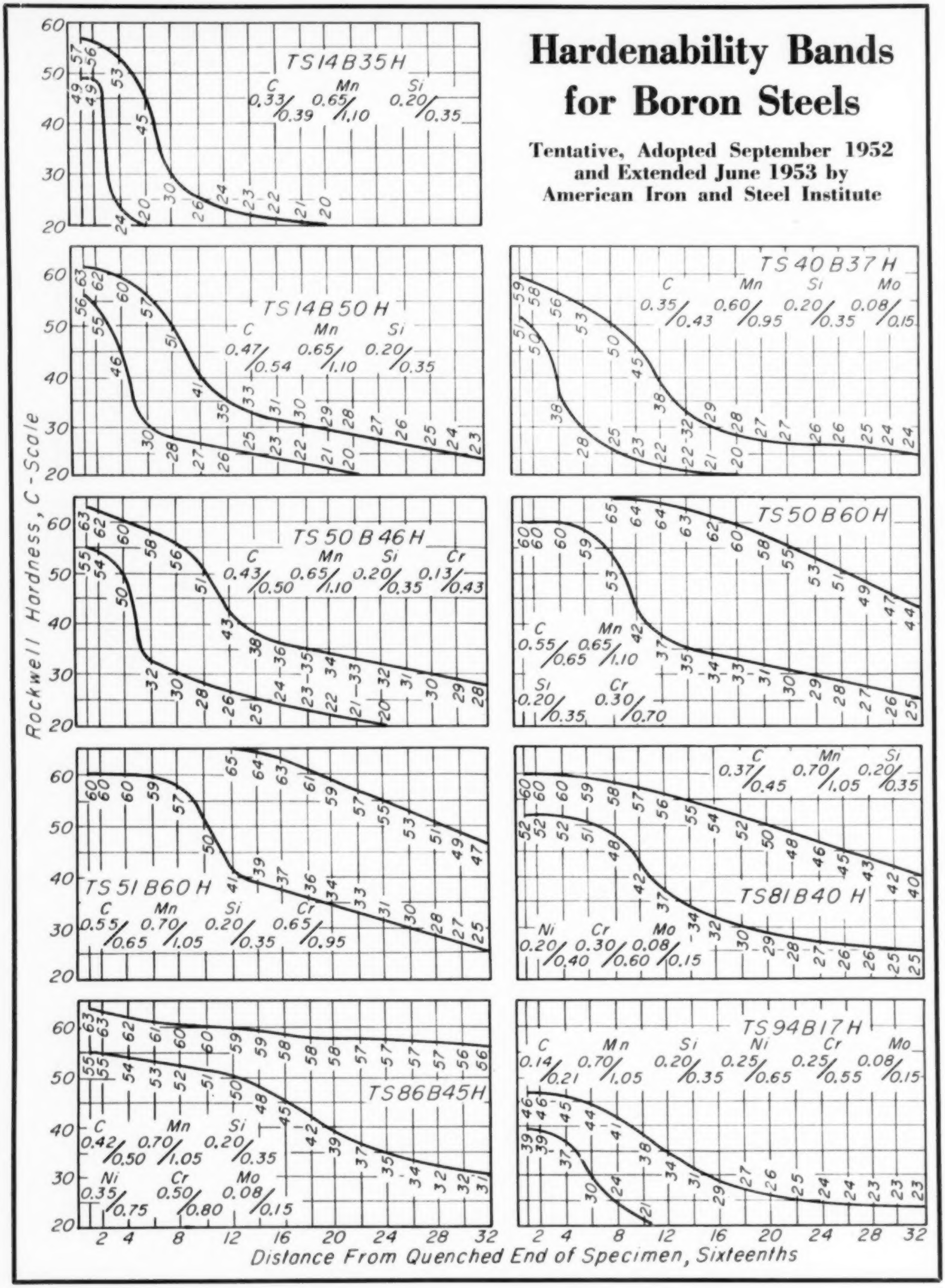

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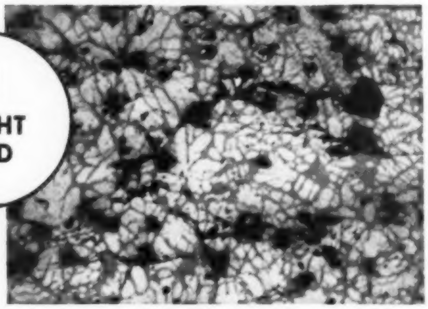

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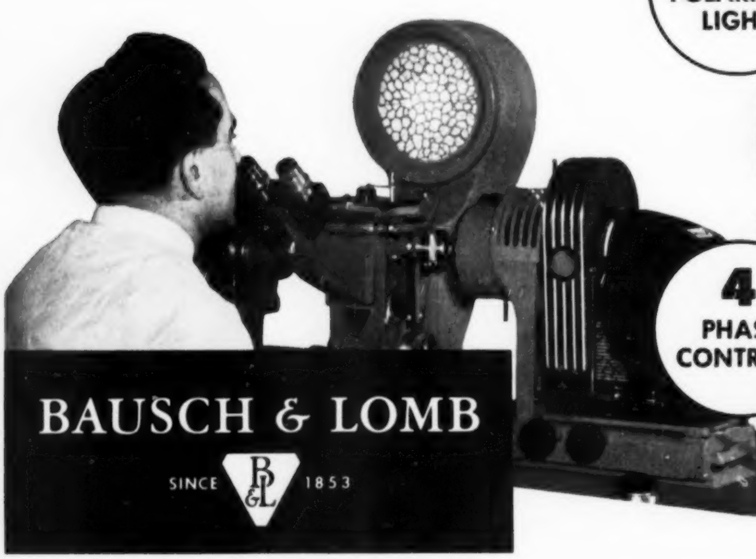

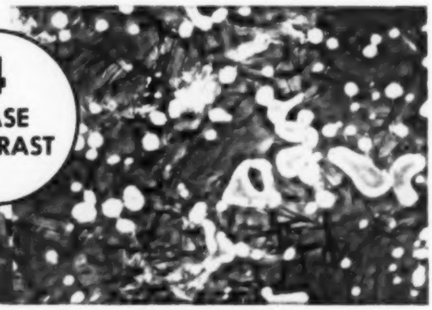

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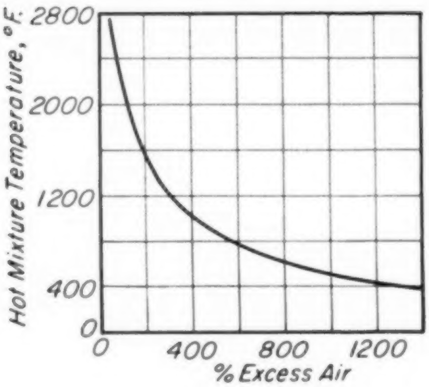

Fig. 1 – Effect of Excess Air on Hot Mixture Temperature. The hot mixture temperature becomes the theoretical flame temperature at 0% excess air

ture when continuously subjected to a nonuniform temperature pattern in a furnace. The false assumption that the conductivity of metal will make up for the shortcomings of a furnace contributes heavily to the scrap pile and is the cause of many heat treating reruns. If the depth to which the heat penetrates a large heavy-sectioned piece is not uniform, the depth of the altered grain structure will not be uniform. This may be particularly serious in pieces that are to be subjected to shock loads, such as tank hulls and turrets, or to very high pressures, such as turbine casings and pressure vessels.

The location of the burners relative to the load being heated is very important. This point is probably obvious to an engineer, but unfortunately, placement of the load is all too often left to the discretion of employees who are unaware of its significance. Most furnaces are used for heating more than one size and shape of load. It is the engineer's responsibility to supply loading instructions and to see that they are carefully carried out. Because it is impractical to design for only one size and shape of load, perfect temperature distribution is unattainable by attention to burner and load location alone.

The addition of large amounts of excess air (more air than is needed for combustion of the fuel being burned) through the burners may

Method for Improving Temperature Uniformity in Furnaces

TEMPERATURE distribution within heat treating furnaces is a critical factor where the hardness of the pieces being treated must conform to a high standard of uniformity. The same is true in enameling, and other ceramic coating processes, where color and finish must be carefully controlled.

When large numbers of small pieces are put into a furnace at one time, there is danger that the hardness or surface quality will not be the same in all parts of the load if the temperature throughout the furnace is not uniform. Careful attention to temperature distribution can reduce the number of rejects. When large pieces are to be heated, the problem is even more acute because the piece itself impairs circulation of the furnace gases. Although metals are comparatively good conductors of heat, large pieces will not "soak out" to a uniform tempera-

By OTTO LUTHERER
Vice-President and Chief Engineer
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Application Engineer
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improve the temperature uniformity in a furnace. The several explanations for this will be given. We think that a better understanding of this phenomenon would improve the use of excess air for uniform temperatures in industrial furnaces; hence the series of tests described herein was conducted.

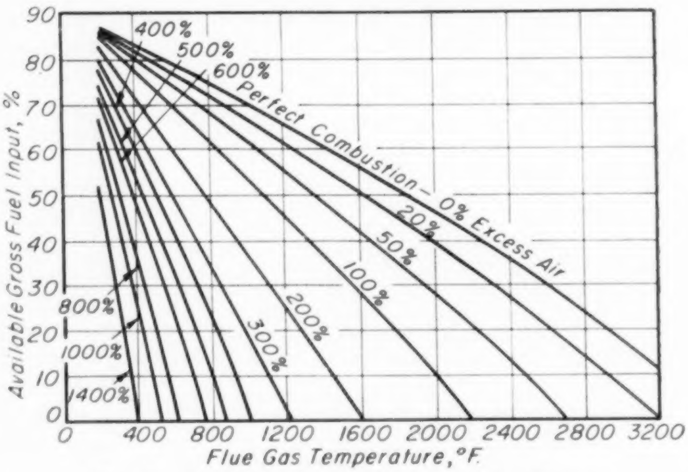


Fig. 2 – Available Heat Chart. Example: If one million Btu. per hr. of useful heat must be released in a furnace having a 1000° F. flue-gas exit temperature and using 300% excess air, this chart shows that 20% of the gross input will be available (useful); therefore the gross fuel input must be one million divided by 0.20 or 5 million Btu. per hr.*

THE EXCESS AIR EFFECT

Hot Mixture Temperature – When an excess of air is suplied through a gas or oil burner, only a small amount of it can be actually mixed with the fuel without crossing the lean flammability limit. Therefore, most of the excess air must pass *around* the flame, and special burner designs are usually required for this. If the excess air and combustion products were thoroughly mixed at some point beyond the flame tip, the temperature of the resulting hot mixture would be considerably less than if no excess air were supplied and perfect combustion achieved. Figure 1 shows the hot mixture temperatures that result from addition of various amounts of excess air.

The "hot mixture temperature" is the highest temperature that exists in a furnace, except for the flame itself which is usually quite small in size relative to the furnace volume. If the burners are arranged in the furnace so as to minimize radiation from the flame to the load, or if the burners can be operated with the flame entirely within the burner tile, then no point on the surface of the load will be hotter than the hot mix temperature. The closer this is to the desired holding temperature, the less is the probability of hot spots and the better the uniformity. It is logical that with smaller temperature differentials in the furnace, there will be smaller temperature differentials in the load.

Lowering of the hot mixture temperature not only reduces the possibility of localized nonuniformity, but also reduces the tendency of the furnace gases to stratify, a condition which causes temperature differentials from the top to the bottom of the furnace. Stratification may be particularly troublesome in tall furnaces with tall loads.

Effective Turndown Ratio – If excess air is used in a furnace, more hot gases go up the stack (other things being equal), the flue loss is greater, and the percent available heat† is less. Figure 2 shows this reduced percent available heat for various amounts of excess aid and flue-gas temperatures. This graph is based on Cleveland natural gas (1060 gross Btu. per cu.ft.), but it may be used for other fuels that release about 100 gross Btu. per cu.ft. of air consumed during perfect combustion.

As the hot mixture temperature is lowered by the use of excess air, the available heat is also lowered, and the thermal efficiency is therefore reduced. This improves the effective turndown ratio (ratio of maximum to minimum input) of the burners, and they can be kept on very low input rates during stand-by periods. If some of the burners had to be turned completely off, to

*This chart is applicable only when there is no unburned fuel in the products of combustion. The average temperature of the hot mixture just beyond the end of the flame may be read at the point where the appropriate % excess air curve intersects the zero available heat line.

†*Available heat* is the gross heat in the fuel minus the moisture loss due to combustion of hydrogen in the fuel and minus the heat carried away in the "dry" gas. It is the heat left for heating the load and balancing wall radiation and door losses. *Percent available heat* is the available heat expressed as a percentage of the gross heat. (Both gross and available heat may be stated in terms of Btu. released per hour or in terms of Btu. contained in a unit of fuel.) It measures the maximum thermal efficiency of the furnace.

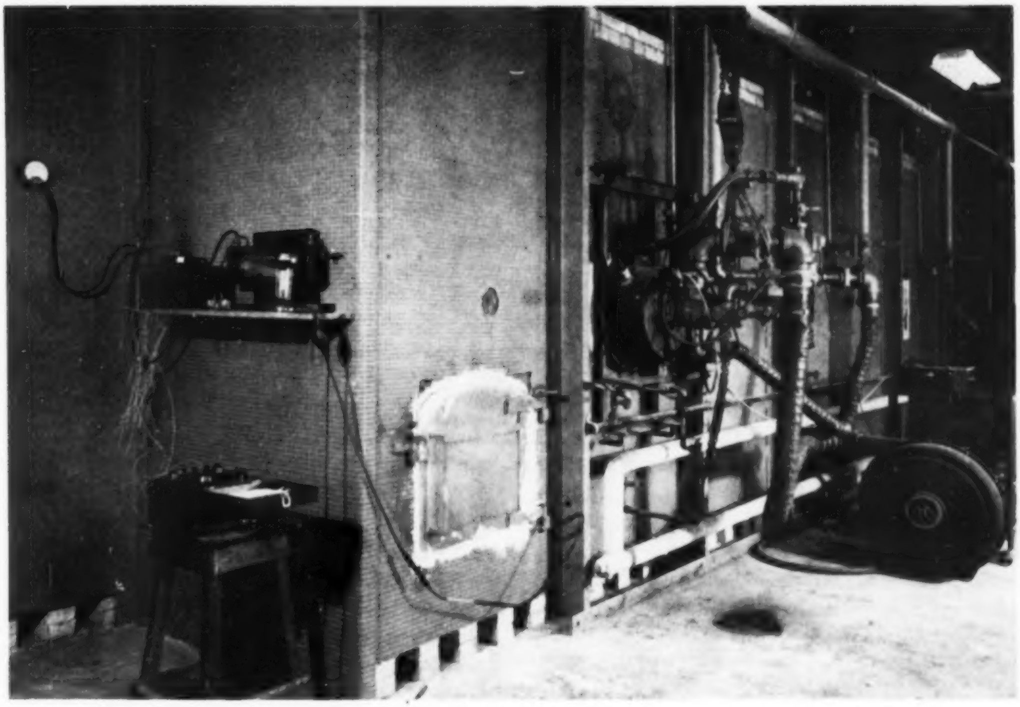


Fig. 3 – Exterior View of Test Furnace Showing Burner and Some of the Test Instruments

avoid exceeding the holding temperatures, that would contribute to nonuniformity; thus the fuel efficiency is intentionally lowered to achieve uniformity. The cost of fuel, however, is usually small compared with the cost of unsatisfactory products.

Cold Air Infiltration – When the pressure in a furnace is less than atmospheric pressure, cold air will be drawn in through any cracks in the furnace setting. This cold air may chill one end or one corner of the furnace or a part of the load. Increasing the firing rate to compensate for this chilling action may just make the other parts hotter, for the temperature distribution is then even worse.

When excess air is used, more air is pumped into the furnace and so the furnace pressure is likely to become positive. This may be sufficient to eliminate cold air infiltration and thus improve the temperature uniformity. One might think at first that it would be simpler to increase the furnace pressure by (*a*) increasing the firing rate of the burners or (*b*) pumping in an extra supply of room air. Method (*a*) would raise the furnace temperature too much for the process unless some means were devised for intentionally increasing the heat loss to compensate for the extra input. This is usually quite inconvenient and the working conditions become less comfortable. Method (*b*) is, in effect, the excess air method. However, if the room air is not admitted to the furnace in such a manner as to facilitate quick mixing with the hot combustion products from the burners, it will do as much harm as cold air infiltration. The only practical way to achieve quick mixing of the room air with the combustion products is to put it through the burners.

An alternate way to increase furnace pressure and stop infiltration is to constrict the flues. In some instances, this may be all the correction that is needed. Three precautions, however, should be observed:

1. The adjustment of the flue openings may be a lengthy trial-and-error procedure because these openings affect the circulation of hot gases in the furnace as well as furnace pressure.

2. There may be a variation of pressure from the top to the bottom of the furnace; therefore it is necessary to make sure that the pressure is positive at the lowest point in the furnace.

3. Leaks in a furnace setting will probably get worse as time goes on, necessitating further adjustment of the flues. The use of excess air may be a palliative, but good furnace maintenance is the best solution.

The Excess Air Effect

Better Agitation – It was mentioned that stratification might cause considerable non-uniformity, particularly in tall furnaces. It is theorized that the additional agitation resulting from the larger volume of hot mixture flowing through the furnace when excess air is used reduces the tendency to stratify. It is also possible that the temperature distribution across the furnace from end to end might be improved due to changes in the circulation pattern. Since there would be a greater volume of gases flowing through the furnace, there could hardly be a change for the worse in the circulation pattern.

Forced Convection – Because more hot gases flow through a furnace when excess air is used, the velocity of the hot gases will be higher. This higher velocity tends to increase the rate of convection of heat. However, excess air also reduces the hot mixture temperature which, in turn, reduces the temperature difference between the source of heat (the hot mixture) and the receiver of heat (the load), thus decreasing rapidly the rate of heat transfer. It is the authors' opinion that there can be little net gain in the heat transfer rate by forced convection unless the furnace is especially designed for this purpose.

Table I–Load and Thermocouple Descriptions

Load Material and Number	Weight of Load, Lb.	Load Size, In.	Thermocouple Height, In.*
1. Cast iron	90	6 diam. x 12	23
2. Cast iron	90	6 diam. x 12	1
3. Cast iron	90	6 diam. x 12	23
4. Cast iron	90	6 diam. x 12	1
5. Cast iron	75	5½ diam. x 12	23
6. Cast iron	75	5½ diam. x 12	1
7. Cast iron	75	5½ diam. x 12	23
8. Cast iron	75	5½ diam. x 12	1
9. Cold rolled steel	0.2235	1 diam. x 1	18
10. Cold rolled steel	0.2235	1 diam. x 1	36
11. Cold rolled steel	0.2235	1 diam. x 1	54
12. Cold rolled steel	0.2235	1 diam. x 1	72

*Height of thermocouple above hearth.

APPLICATION OF EXCESS AIR

The use of excess air to improve temperature uniformity is probably applicable for any heating process within the range from 400 to 1800° F., wherein an oxidizing atmosphere is not harmful. Above this range, the percentage of available heat becomes so small that fuel costs are prohibitive.

All of the five theories discussed may be used to explain why better uniformity is achieved with a recirculating type of furnace or oven wherein one burner is installed in an outside combustion chamber and the gases are continually circulated by a fan. Cost determines whether a recirculating system or excess air

Table II–Data Recorded at Equilibrium in Seven Tests

Test Data	Test Number						
	1	2	3	4	5	6	7
% Excess air	0	223	0	223	0	223	0
% CO_2 in furnace atmosphere	4.25	3.25	5.5	–	11.25	3.5	10
Gas flow, cu. ft. per hr.	700	700	700	700	700	700	298
Furnace pressure (at hearth), in. H_2O	−0.035	−0.035	−0.045	−0.045	+0.098	+1.138	+0.008
Temperature, °F.							
Load 1	910	840	925	845	1316	1086	983
Load 2	795	805	815	815	1200	1060	931
Load 3	820	840	845	850	1235	1121	939
Load 4	775	830	815	840	1169	1080	925
Load 5	845	825	865	835	1263	1085	951
Load 6	800	805	825	820	1194	1072	938
Load 7	810	760	815	740	1144	1014	921
Load 8	745	735	785	730	1126	1005	911
Load 9	–	–	835	770	1173	1037	933
Load 10	–	–	860	785	1188	1030	939
Load 11	–	–	875	785	1202	1027	947
Load 12	–	–	895	790	1205	1030	958

burners should be used. At higher temperatures, the cost of the recirculating fan and high-temperature ductwork usually favors more air burners. At low temperatures, the saving resulting from the use of only one burner, combined with the better fuel efficiency of a recirculating system, reverses the situation for economical operation.

A very important application of excess air is in multiple-purpose furnaces which must be operated at high temperatures during some periods and cooler at other times. Such furnaces are operated with little or no excess air for high-temperature operations and with larger amounts of excess air when the lower temperatures are required.

Test Program to Establish Theories

TEST PROCEDURE

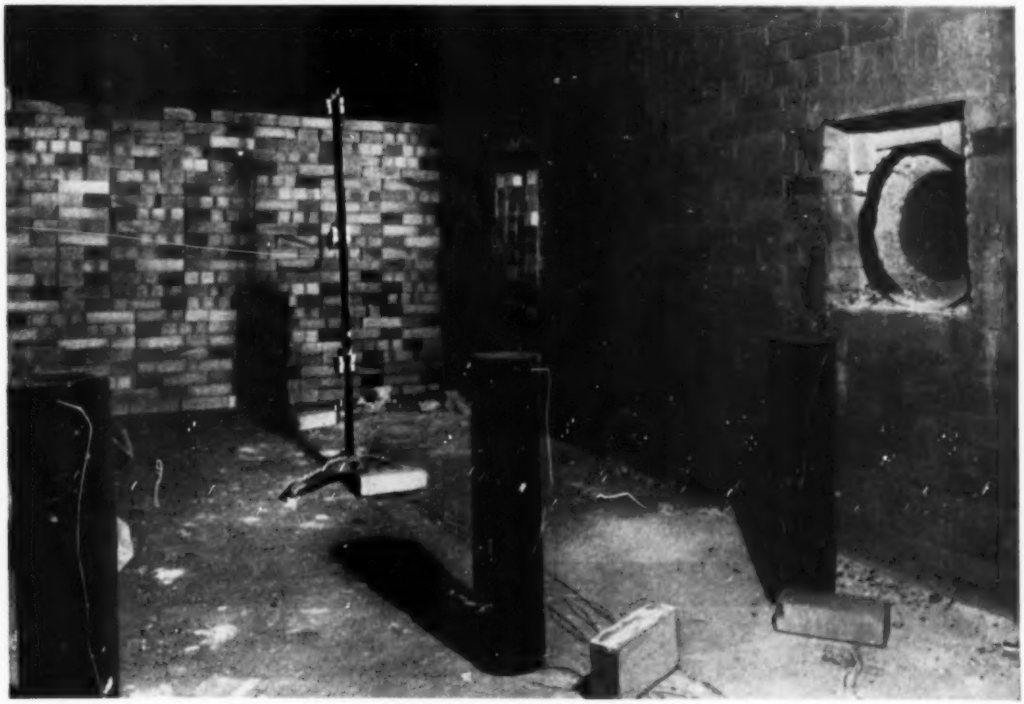
Seven tests were conducted in an attempt to establish which of the previously discussed theories was dominant.

The furnace was of conventional shape and construction; Fig. 3 is an exterior view. It was fired with only one large burner; thus the test for uniformity was more severe. A 5-ft. baffle wall which had been used in previous tests was left in place so as to shorten the furnace's effective length. Since the size and shape of the load and the relative positions of the load and burners affect the paths so much, it was decided that no particular type of load should be simulated. Loads were placed so that their temperatures would indicate the temperature distribution in the vertical, horizontal north-south, and horizontal east-west directions. Iron-constantan thermocouples were embedded ¼ in. below the surface of the cylindrical cast iron loads. Figure 4 is an interior view and Fig. 5 on p. 118 shows the exact location of the loads and the thermocouples.

The dimensions, weights and descriptions of the loads are given in Table I.

During the first four tests, the temperatures were read with a millivoltmeter calibrated for iron-constantan thermocouples and having an accuracy of $\pm 5°$ F. During the last three tests, a Wheatstone bridge potentiometer with an accuracy of $\pm \frac{1}{2}°$ F. was used. The furnace gases were analyzed for CO_2 with an absorption type (Orsat) analyzer. Inclined-tube manometers measured furnace pressure and flow of natural gas fuel. The air orifice of the burner had been calibrated for various pressures at the

Fig. 4 – Interior of the Test Furnace Showing Burner, Loads, Thermocouples, and Baffle Wall



Analysis of Temperature Variations

air connection, so the air flow was determined by a U-tube manometer.

During Tests 1, 3, 5 and 7, the burner was operated on correct gas-air ratio; during Tests 2, 4, and 6, the burner was operated with 223% excess air. Tests 1, 2, 3, and 4 were conducted with a negative pressure in the furnace, and Tests 5, 6, and 7 with a positive pressure. The fuel input was approximately the same (700 cu.ft. per hr. of natural gas, 0.635 gas gravity, 1059 gross Btu. per cu.ft.) during all but Test 7. For the latter, the fuel input was reduced to provide approximately the same available heat when operating "on ratio" as had been supplied in Test 6 when operating with an excess of air. Note that there were no small loads arranged at 18-in. intervals between the hearth and the arch in Tests 1 and 2.

VERTICAL TEMPERATURE DISTRIBUTION

Table II lists the data recorded when equilibrium was reached in each of the seven tests, plus the pertinent information concerning the furnace conditions under which each test was conducted.

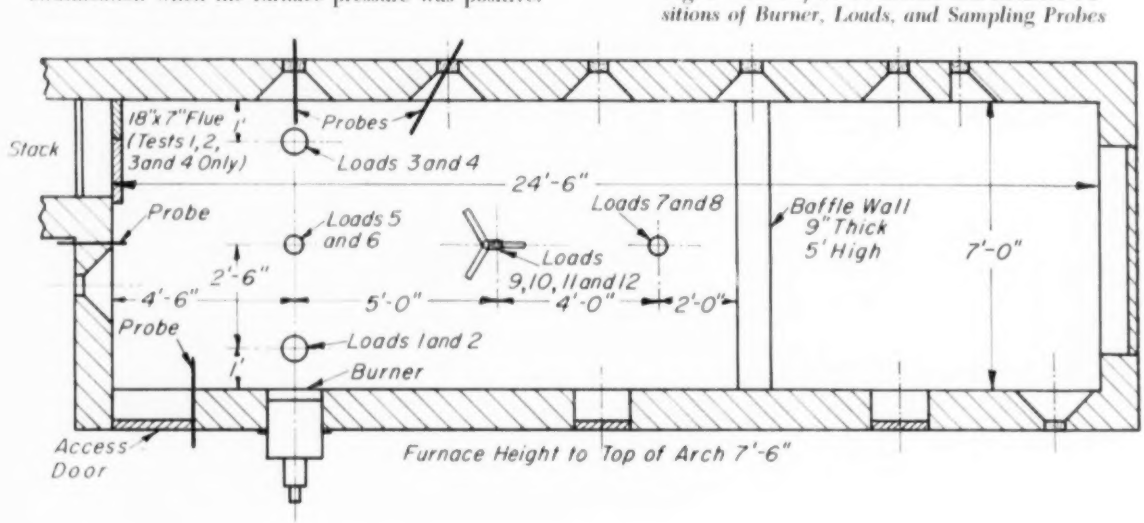
Table III gives an analysis of the temperature variations in the vertical direction. Line 5 lists the maximum temperature differential between the four small loads (3.5 oz. each) located 1½, 3, 4½, and 6 ft. above the hearth. The addition of excess air resulted in a reduction of 15 to 40° F. in this differential. The differential was less when the furnace pressure was positive. Since these loads were about in the center of the furnace and considerably above the hearth, it is quite unlikely that the change in differential with change in furnace pressure was due to more or less cold air infiltration.* The temperature pattern for these four small loads was almost completely reversed in Test 6 with excess air, the hottest being nearest the hearth, and the coolest being the second from the top.

Line 8 of Table III lists the average of the temperatures indicated by the thermocouples located at the tops of the 75 and 90-lb. loads, 23 in. above the hearth. Line 9 gives average temperatures at the bottom of these loads, 1 in. above the hearth. Line 10 shows the difference between these top and bottom averages. Lines 11, 12, and 13 list figures corresponding to those on Lines 8, 9, and 10, but omit the data on the one large load that was not on the burner centerline. These data on the larger loads again illustrate (except in the last test) the large gain in vertical uniformity resulting from the use of excess air.

The discrepancy of the last test is only partially explained. As the average temperature level in a furnace rises, the tendency for vertical nonuniformity becomes greater; thus, if Test 7

*It can, however, be explained in terms of circulation. During the negative pressure tests, the bulk of the flue gases left the furnace via an 18x7½-in. opening, the position of which makes it very improbable that there would be much motion of hot mixture into the locality of the small loads. Thus, there was less agitation and more stratification in this area when the pressure was negative. When positive, the only exits were leaks in the furnace walls, and the general direction of hot mixture flow was probably toward, rather than away from, the small loads. This would minimize stratification when the furnace pressure was positive.

Fig. 5 – Plan of Test Furnace and Relative Positions of Burner, Loads, and Sampling Probes



had been run at the same temperature as Test 6 instead of cooler, the temperature difference would probably have been greater in Test 7, as it was in the other on-ratio tests. Another explanation is that with the lower input rate used in Test 7, there is a greater chance for the temperatures to level out.

It is important to note from Lines 10 and 13 that the furnace pressure did not make any difference in the temperature differential of the large loads. Since the lower couples on the large loads were only 1 in. from the hearth, as compared with 18 in. for the small loads, one would expect the cold air infiltration resulting from a negative furnace pressure to cause more variability in the large loads.

It is our conclusion that the principal gain in vertical uniformity is due to reduced hot mix temperature and increased agitation. Furnace pressure only affects uniformity by changing the circulation and by stopping cold air infiltration, both of which are unpredictable. These tests prove that the benefits of excess air can arise from other effects, and that the resultant gain in uniformity can be substantial.

HORIZONTAL TEMPERATURE DISTRIBUTION

Figure 6 on the next page shows the temperature patterns for the seven tests along lines parallel to the center line of the burner, and Fig. 7 shows the temperature distribution along a horizontal line perpendicular to the burner centerline.

The test arrangement, with only one burner located in the end of a furnace, is not a proper design for any furnace wherein uniformity is critical. Most of the temperature variations in the horizontal plane can be explained by the effects of circulation and flame radiation, but since these factors vary with the furnace arrangement (which is not too good in this example), there is little value in discussing them in this connection.

One conclusion that can be drawn from the data on horizontal temperature distribution, however, is that a change from negative to positive furnace pressure had no appreciable effect on the temperature patterns.

CONCLUSIONS

1. Excess air improves the temperature uniformity in a heat treating furnace, particularly in the vertical direction

2. While it is possible to improve uniformity by reducing cold air infiltration, this is not necessarily the only or the major gain to be achieved through the use of excess air.

3. A combination of good furnace mainte-

Table III—Analysis of Vertical Temperature Distribution

Line No.	Conditions and Temperature Patterns	Test No. 1	2	3	4	5	6	7
1	% Excess air	0	223	0	223	0	223	0
2	% CO_2 in furnace atmosphere	4.25	3.25	5.5	—	11.25	3.5	10
3	Gas flow, cu.ft. per hr.	700	700	700	700	700	700	298
4	Furnace pressure (at hearth), in in. H_2O	−0.035	−0.035	−0.045	−0.045	+0.098	+1.138	+0.008
5	Maximum differential for loads 9, 10, 11, 12; °F.	—	—	60	20	33	10	26
6	Maximum differential for loads 1, 2, 3, 4, 5, 6; °F.	135	35	110	35	147	61	59
7	Maximum differential for loads 1,2,3,4,5,6,7,8; °F.	165	105	140	120	190	115	73
8	Average temperature of top loads 1, 3, 5, 7; °F.	846	816	863	818	1240	1076	949
9	Average temperature of bottom loads 2, 4, 6, 8; °F.	779	794	810	801	1172	1054	926
10	Average differential for top to bottom loads, °F.	67	22	53	17	68	22	23
11	Average temperature of top loads 1, 3, 5; °F.	858	835	878	843	1272	1097	958
12	Average temperature of bottom loads 2, 4, 6; °F.	790	813	818	825	1188	1070	931
13	Average differential for top to bottom loads, °F.	68	22	60	18	84	27	27

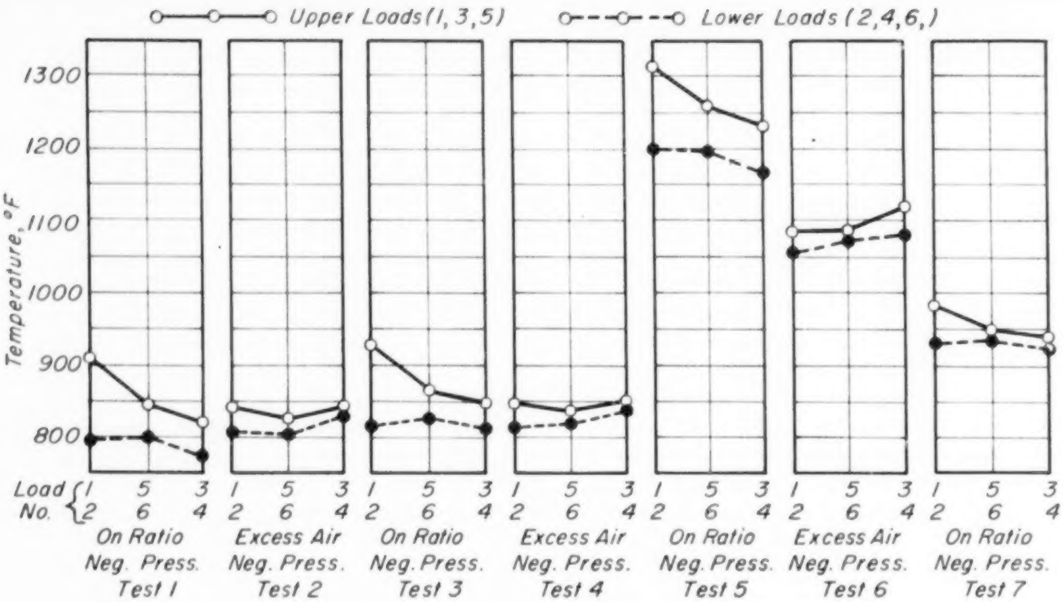


Fig. 6 – Temperature Patterns Along the Burner Centerline

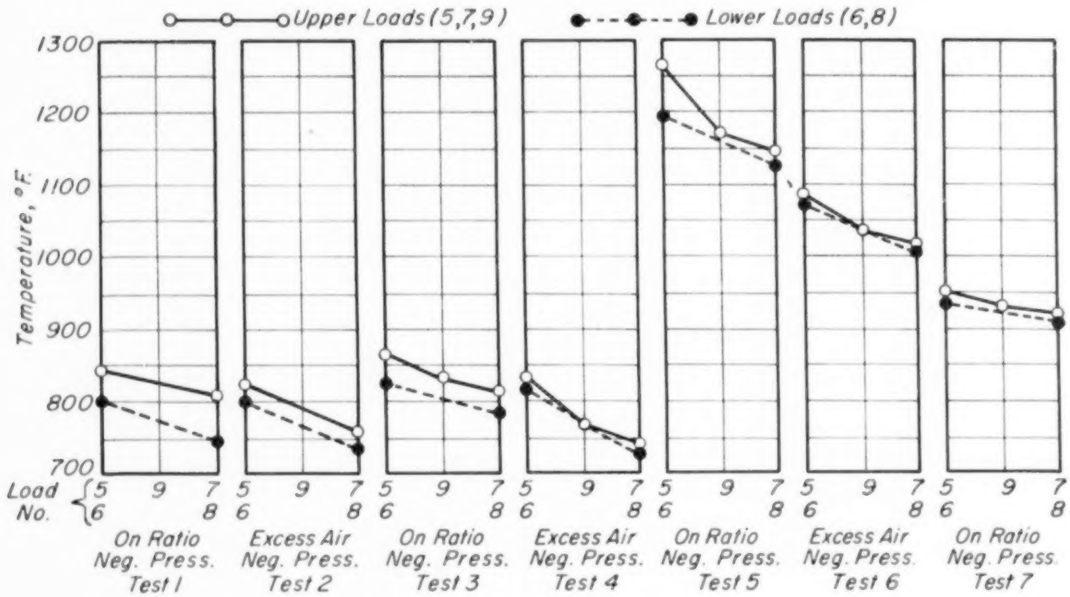
nance and the use of excess air is the surest way to eliminate cold spots that are caused by infiltration of cold air.

4. Excess air may be used to advantage in batch-type and multiple-purpose furnaces (where high turndown ratios are required) because it eliminates the need for manual turning off of burners.

5. The theory that the forced-convection heat transfer rate is increased by the use of excess air is very questionable.

6. By the process of elimination, the reduction of the hot mixture temperature and the increased agitation of furnace gases must be good reasons for the improved temperature uniformity resulting from use of excess air.

Fig. 7 – Temperature Patterns Along a Horizontal Line Perpendicular to the Burner Centerline



A Combination Mill for Experimental Rolling of the "New" Metals

By A. I. NUSSBAUM, Rolling Mill Division
Stanat Mfg. Co., Long Island City, N. Y.

THE INCREASING demand for such potentially important engineering materials as titanium, zirconium, molybdenum, tungsten, tantalum, columbium and vanadium in the form of bar, rod and strip has led to much current research on both hot and cold rolling. Primary production of most of these metals is still a difficult process, involving such special techniques as arc and induction melting, and compacting and sintering by powder metallurgical methods. Fortunately, the subsequent hot and cold working procedures are generally more conventional, although the workability of these metals varies widely. Tantalum, for example, has excellent ductility, molybdenum is susceptible to cracking, and tungsten is extremely brittle at room temperature. Expressed numerically in terms of mechanical properties, the range of cold working characteristics of these three metals (produced by powder metallurgy) may be summarized as follows:

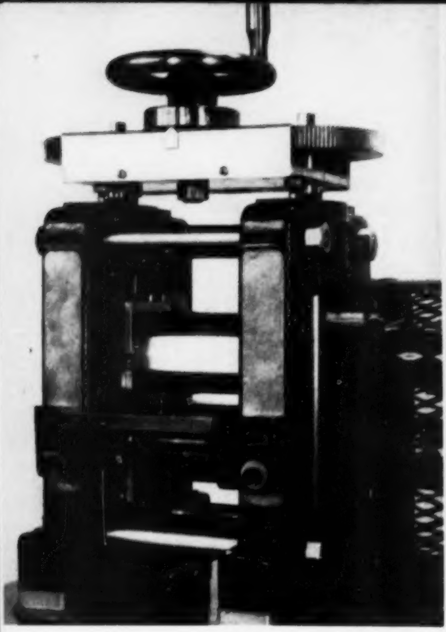
Cold Worked Strip	Thickness	Tensile Strength	Rockwell Hardness
Tantalum	0.010 in.	110,000 psi.	B-63
Molybdenum	0.010	175,000	C-27
Tungsten	0.010	300,000	C-47

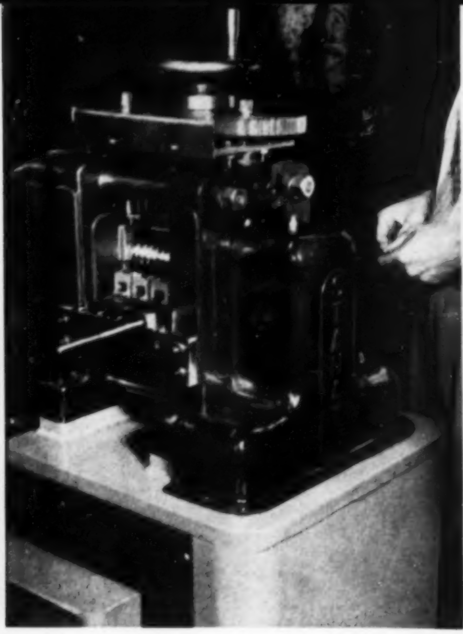
These figures show the wide range of loading imposed upon equipment that is required to cold roll some or all of these metals from initial ingot breakdown to ultra-thin strip (in the neighborhood of 0.001 in.). This problem can be solved easily in high-production plants, where the quantities processed justify the installation of a series of rolling mills to take the product through the several stages of cold reduction. On the other hand, the many research laboratories and pilot plants that are faced with the problem of processing metals such as tantalum, molybdenum and tungsten in experimental quantities clearly cannot afford the range of individual mills normally required to take a 2-in. ingot down to 36-gage strip.

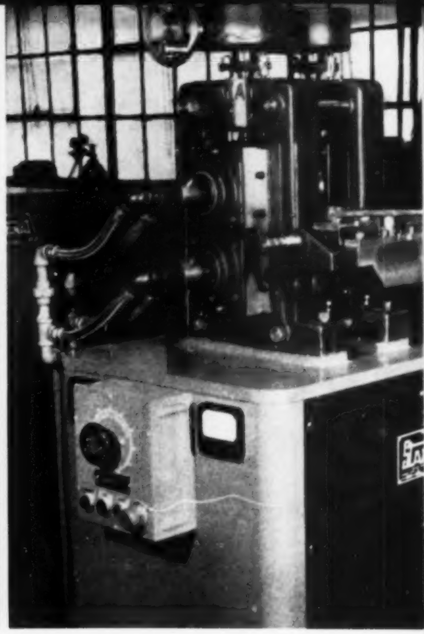
Furthermore, it has been found time and again that it is impractical to do experimental rolling on production mills. Such test runs usually interfere with plant production schedules and may cause friction between mill personnel and research staff. Badly needed, therefore, is a precision mill capable of the widest possible range of bar, rod and strip reduction, available at a price within reach of the limited budgets of research organizations and compactly designed to fit into the restricted space of metallurgical laboratories. A combination two-high and four-high mill has been developed to fill this need.

TWO-HIGH OPERATION

When functioning as a conventional two-high unit, the mill has a relatively large work roll for breakdown of ingots and bars, reduction of strip requiring high luster, and for skin passing of annealed strip. Apart from power considerations, the determining factor for breakdown rolling is generally the maximum draft per pass that can be taken with the material entering the rolls unassisted. This maximum possible draft varies with the work roll diameter, in accordance with the following equation:







Left – Combination Two-High and Four-High Mill, With Flat Rolls for Reduction of Strip. Center – Grooved roll set-up for reduction of rounds. Right – Combination mill equipped for "warm" rolling. Flexible hose lines at left carry heated fluid into central cavity in the rolls

$$h_o - h_i = D(1 - \cos f)$$

where h_o = thickness of material at entry, in.
h_i = thickness of material at exist, in.
D = diameter of work rolls, in.
f = friction angle = $\tan^{-1}\mu$
and μ = coefficient of friction between work rolls and material

In normal rolling practice, the value of μ may vary from 0.05 for smooth rolls and a palm oil lubricant to 0.30 for dry sand-blasted rolls. From the above relationship, it may be seen that, taking μ as 0.15 (corresponding to a friction angle of 8.5°), a 2-in. and 8 x 8-in. four-high mill could take a reduction of only 0.022 in. or 2.2% on a 1-in. ingot, while an 8 x 8-in. two-high mill could reduce that same ingot 0.088 in. or 8.8% per pass with unaided entry of the material. Since the maximum possible contact angle in rolling is twice the friction angle, the above mills would be capable, respectively, of 0.084 in. or 8.4% and 0.336 in. or 33.6% reduction per pass. These extreme values assume that the material is pushed or the entry edge of the ingot is tapered to help it enter the roll bite.

Work rolls should be of relatively large diameter for skin pass rolling of annealed strip, when a reduction of only about 1½% is usually desired. Such rolls are also advantageous for reducing strip with little or no lubricant so as to obtain a bright and highly burnished surface finish. This luster effect is directly due to the fact that the larger the work roll diameter the greater the amount of slipping between roll surface and material.

Finally, the two-high mill is still preferred for mirror-finished strip where extremely hard and close-grained rolls are used, superfinished to 1 to 2 micro-in. rms. by lapping with diamond compound. In such ultra-precision work it is not desirable to have a continuous line contact between the work and back-up rolls, and the work rolls can be wiped with felt pads more readily in the two-high design. Furthermore, a larger diameter work roll with its greater circumference will wear relatively less and thus perform better and longer between grindings.

FOUR-HIGH OPERATION

Almost every engineer or metallurgist using a two-high strip mill in the laboratory sooner or later becomes stymied by the inability of his completely screwed-down mill to produce any further gage reduction. Even an additional intermediate anneal may be of little help, and the only solution is to continue processing the strip on four-high or cluster mills having considerably smaller work rolls backed up by large supporting rolls.

The concept of a combination two-high and four-high mill was developed particularly to overcome this situation. It may be considered primarily as a two-high mill designed so that the rolls can be raised sufficiently to insert between them a set of two small-diameter work rolls. Alternatively, it may be regarded as a four-high mill with driven back-up rolls designed to facilitate rapid changeover to a conventional two-high configuration by the withdrawal of the two work rolls. (*Continued on page 162*)

Fig. 1 – Sand-Blasting the Girders of a Railroad Bridge Prior to Painting

By JOSEPH BIGOS
Senior Fellow, Mellon Institute
and Director of Research
Steel Structures Painting Council
Pittsburgh

Surface Preparation of Steel for Painting

PAINTS ARE WIDELY used to protect metals from corrosion, but the correct preparation of the surface on which they are to be used is not so widely understood. Poor or wrong cleaning will defeat the function of any paint, regardless of how well the paint is suited for the particular environment it will encounter in service. The paint must be applied to a clean surface, otherwise it will give poor protection or will not adhere.

In the interests of establishing good practice in the cleaning of structural steel surfaces prior to painting, the Steel Structures Painting Council, Pittsburgh, has issued a series of nine tentative specifications pertaining to: (*a*) solvent cleaning, (*b*) hand cleaning, (*c*) power tool cleaning, (*d*) flame cleaning of new steel, (*e*) blast cleaning to "white" metal, (*f*) commercial blast cleaning, (*g*) brush-off blast cleaning, (*h*) pickling, (*i*) weathering and cleaning. This article is based on the procedures recommended in these specifications (which were prepared in collaboration with representatives of various organizations concerned with the cleaning and painting of steel), and will describe all of the methods except those pertaining to blast cleaning* and weathering.

SOLVENT CLEANING

Solvents clean the metal by dissolving and diluting the foreign matter such as oil, grease, soil, and drawing and cutting compounds. Solvent cleaning includes the use of emulsions, cleaning compounds, steam or other materials and methods which may not, strictly speaking, involve a solvent action.

The usual sequence of operations is to remove soil, cement spatter, drawing compounds, salts, or other foreign matter (other than grease or oil) by brushing with stiff fiber or wire brushes, or by scraping, or by cleaning with solutions of either emulsion or alkaline cleaners, provided the latter are followed by a fresh water rinse, or by a combination of these methods.

Oil or grease may be removed by wiping or

*Editor's Note: The subject of blast cleaning will be explained in a subsequent article.

scrubbing the surface with rags or brushes wetted with solvent, with a final wiping with clean solvent and clean rags or brushes. A solvent spray may be used, or vapor degreasing using stabilized chlorinated hydrocarbon solvents. Another procedure is complete immersion in a tank or tanks of solvent. The solvent for the last immersion should not contain detrimental amounts of contaminant. Steam cleaning, with or without detergents or cleaners, may be used, provided that the surface is finally steamed or washed to remove detrimental residues of cleaning compounds.

If chemical paint strippers are used for the removal of paint, any wax from the stripper remaining on the surface must be removed by the use of suitable solvents. Alkaline residues from the paint strippers can be removed by washing the surface with fresh water. The surface must be free of all detrimental paint and stripping agent residue.

It is important that solvent-cleaned surfaces be primed or otherwise protected immediately after cleaning so they will not corrode or become recontaminated.

Types of Solvents – Petroleum-base mineral spirits (aliphatics) with a minimum flash point of 100° F. (or "Stoddard Solvent", A.S.T.M. Specification D 484-40) should be used as the general purpose solvent for cleaning under normal conditions. In hot weather, or when the temperature is about 80 to 95° F., mineral spirits with a minimum flash point of 120° F. should be used. In very hot weather, when the temperature is above 95° F., heavy mineral spirits with a flash point above 140° F. should be used. Gasoline and V.M.&P. naphtha are too dangerous for use under ordinary conditions.

"Safety solvents" are satisfactory if they meet the flash point requirements given in the preceding paragraph and provided these are not lowered by evaporation during use. Also, the use of safety solvents must be such that the concentration of chlorinated hydrocarbon in air does not constitute a health hazard.

Aromatic or coal tar solvents are more active solvents than the preceding group, but they are more toxic and the solvents which are generally available have low flash points. Benzol (benzene) is the most toxic and explosive; it should not be used. Xylol and toluol may be used when their concentration in air does not exceed the lower explosive limit; if the concentration is greater than the maximum allowable for breathing but below the lower explosive limit, work may proceed but fresh air masks must be worn. Because of the low flash points of these solvents, fire and explosion hazards are inherent with their use and great caution must be taken to insure safe working conditions. Chlorinated hydrocarbons may be used; but, due to their toxicity, they are not recommended for general use except with special equipment and trained operators.

Alkaline Cleaners – These saponify certain oils and greases and their surface-active con-

Fig. 2 – The Steam Cleaning Operation Shown at Left is Followed by a Final Rinse With Hot Water to Remove All Detergent. Fig. 3 – (Below, Left) Hand Cleaning Methods Include Chipping to Remove Loose Scale and Rust, Followed by Wirebrushing. Fig. 4 – (Below) Power Tools Can Also Be Used for Wirebrushing

stituents wash away other types of contaminants, such as soil. They may be particularly effective in removing paint because the alkali saponifies the dried paint vehicle. Since the soaps formed are soluble in water, the contaminants are more easily removed by washing with water after saponification, and the adhesion of old paint is reduced by chemical action. The most common alkaline cleaner is trisodium phosphate but other alkalies are used, some as mixtures with wetting agents and detergents. They are available as proprietary products and specific directions for use are usually recommended by the manufacturer.

A soap film left on the surface is just as damaging to the paint bond as is an oil or grease film; therefore, the surface must be thoroughly washed (preferably with hot water under pressure) to remove this soap and other residue. Moreover, all alkali must be thoroughly removed from the surface or the new paint will be saponified and damaged by it. Because of the paint removal action of many alkaline cleaners, the actual cleaner to be used should be chosen after consideration of the extent to which the paint may be damaged.

If no manufactured alkaline cleaner is available, good results may be achieved by using about 2 oz. trisodium phosphate per gal. of water, to which is added 1 to 2 oz. soap or a suitable amount of other detergent. This concentration is suitable for spraying or scrubbing; if used in dip tanks, the concentration may be tripled. If not washed from the surface, this mixture will soften and eventually loosen most paints. Where complete paint removal is the primary object, caustic soda (sodium hydroxide) may be substituted for the trisodium phosphate. The hotter the solution used, the more effective the removal by these compounds.

The cleaned surfaces must be thoroughly washed with water to remove residues of alkalis. This water should be hot and under pressure. To test the effectiveness of the wash, universal pH test paper should be placed against the wet steel. The pH of the washed surface should be no greater than of the wash water. Following this rinse, steel surfaces should be passivated by rinsing with an acidic wash containing about 0.1% (by weight) chromic acid, sodium dichromate, or potassium dichromate, to neutralize traces of remaining alkali. This passivating rinse may be applied by brushing, spraying, or dipping. Chromate rinses should not be used when chromate-free phosphatizing operations are to follow.

Emulsion Cleaners – These cleaners usually contain oil soluble soaps or emulsifying agents along with kerosene or mineral spirits, and generally are supplied as a concentrate. After it has been thinned with kerosene or mineral spirits and sprayed on the surface to be cleaned, water under pressure is sprayed on the surface, which emulsifies the cleaner and washes it away along with oil, grease, and other contaminants. The cleaners may also be diluted with water and emulsified before use. Manufacturers' directions should be followed.

The residue of emulsion which almost always remains will leave a thin film of oil on the surface. If the paint cannot be applied on this slight amount of oil, the residue must be washed from the surface by steam, hot water, detergents, solvents, or alkaline cleaning compounds.

Also available are alkaline emulsion cleaners. These combine the advantages of the alkaline and emulsion cleaners.

Steam Cleaning – Either steam or hot water under pressure or both can be used in this method of cleaning. The steam and hot water are usually employed with a detergent and sometimes also with an alkaline cleaner. The steam and hot water themselves tend to remove the oils, greases and soaps by thinning them with heat, emulsifying them, and diluting them with water. When steam is used to remove old

Fig. 5 – Rotary Scaler Being Used to Clean a Piece of Sheet Steel

Fig. 6 – A Large Steel Plate Being Lowered Into a Sulphuric Acid Pickling Bath

Hand and Power Cleaning Tools

paint, the vehicle of the paint is cooked so that it loses its strength and its bond to the metal. The detergent, having a higher affinity for the metal, causes the oil, grease and paint to loosen. New paint will not adhere to the metal if any of the oil, grease, soap, detergent, or alkali is left on the surface. A final washing with clean hot water is always necessary.

HAND CLEANING

This method prepares metal surfaces for painting by removing loose detrimental foreign matter, such as mill scale, loose rust, and loose paint, by hand methods such as brushing, sanding, scraping, chipping, or other impact tools, or by a combination of these methods.

After the oil, grease, soil or salts have been removed by the methods outlined under "Solvent Cleaning", other detrimental foreign matter is removed by the following operations:

1. Stratified rust (rust-scale) should be removed by hand hammering, hand chipping, other hand impact tools, or a combination of them. All loose mill scale and all loose or nonadherent rust (that which can be removed from a steel surface by vigorous hand brushing with a wire brush of suitable type at a rate of 2 sq. ft. per min.) should be removed by wirebrushing, sanding, scraping, or by a combination of these methods.

2. In preparing surfaces for repainting, all loose or nonadherent paint must be removed. Thick edges of remaining old paint should be feathered so that the repainted surface can have a smooth appearance and this remaining paint should have sufficient adhesion so that it cannot be lifted as a layer with the blade of a putty knife.

3. All accessible weld flux and spatter should be removed by scraping or by impact tools, after which the area is wirebrushed. In addition, all rivets, welds, corners, joints, and openings should be cleaned.

4. The pre-treatment or the prime coat of paint should be applied as soon as possible before deterioration of the surface occurs.

POWER TOOL CLEANING

Metal surfaces can be prepared for painting by removing loose mill scale, loose rust, and loose paint with power wirebrushes, impact tools, grinders, or sanders, or by a combination of these methods. The objectives for cleaning with power tools are the same as those described for hand cleaning.

It is axiomatic that the brushes, rotary, radial or cup, be of suitable size so as to permit entry into all accessible openings, angles, joints, and corners. The steel wire of such brushes should have sufficient rigidity to clean the surface. Other tools which are suitable for this method of cleaning are chipping or scaling hammers, rotary scalers, single or multiple piston scalers, and similar impact cleaning tools.

Mill scale, rust, and paint are classified as "loose" if they can be removed by wirebrushing with a commercial air or electric machine operated under load at 3450 rpm. and equipped with a 6-in. diameter cup brush, of double-row knotted construction, made of No. 20 gage music wire (Osborn Mfg. Co., Cleveland, brush No. 4503 or equal). The brush should be held against the steel surface with a force of 16 lb., and the rate of cleaning should be 2 sq. ft. of surface per min.

The tools need to be operated with sufficient care that no burrs or sharp ridges are left on the surface and no sharp cuts are made into the steel. If areas are inaccessible to power tools, they should be cleaned by hand methods when they are accessible for the latter.

FLAME CLEANING OF NEW STEEL

Unpainted metal surfaces can be prepared for painting by passing high-velocity oxy-acetylene flames over the entire surface to loosen mill scale and remove moisture. Promptly after application of the flames, the surface of the steel is wirebrushed, hand scraped if necessary, and then swept and dusted to remove all free material and particles of foreign matter. The prime coat must be applied to all flame-cleaned surfaces promptly after the steel has been cleaned and while the temperature of the steel is still well above that of the surrounding atmosphere so that there will be no condensation of moisture on clean surfaces.

However, before flame cleaning operations begin, oil, grease, or other foreign matter has to be removed by methods outlined in the section on solvent cleaning. All of these operations have to be carried out far enough in advance to assure the vaporization and removal of all solvents before application of flames. After this, the accessible welding flux and spatter are removed.

A neutral oxy-acetylene flame is used, this being adjusted so that the length of the inner

(Continued on p. 154)

Correspondence

Piping Causes Freak (but Perfect) Separation

GROTON, CONN.

THE PHOTOGRAPH and micrograph illustrate an unusual incident that occurred recently in our engineering laboratory.

While the "collar", shown at the left, and the "plunger", shown at the right of Fig. 1, seem to have been machined individually, both were originally one piece of steel rod. However, a separation occurred during the recessing operation, and this separation exposed a dark coating on the "plunger head".

In order to examine this coating, the so-called collar was replaced on the parent rod and a transverse section was then removed for metallography, with the results shown in Fig. 2. Examination showed that the coating was slag. Apparently ingot cropping was not sufficient, and some pipe was retained in that portion of the ingot which was subjected to the rolling operation. The defect was then rolled out to make possible the results shown here.

What is most interesting – other than such a continuous slag streak – is that the collar exhibits a perfect annular contour, and the inside diameter and outside diameter have almost perfect concentricity.

HENRY J. ALBERT
Chief Metallurgist
Electric Boat Div.
General Dynamics Corp.

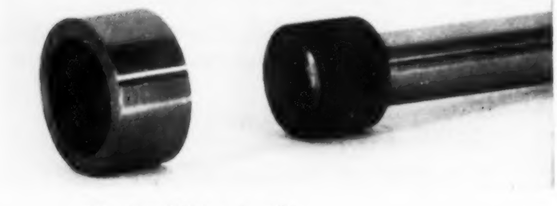


Fig. 1 – Piping in Machined Rod Caused It to Separate as Shown

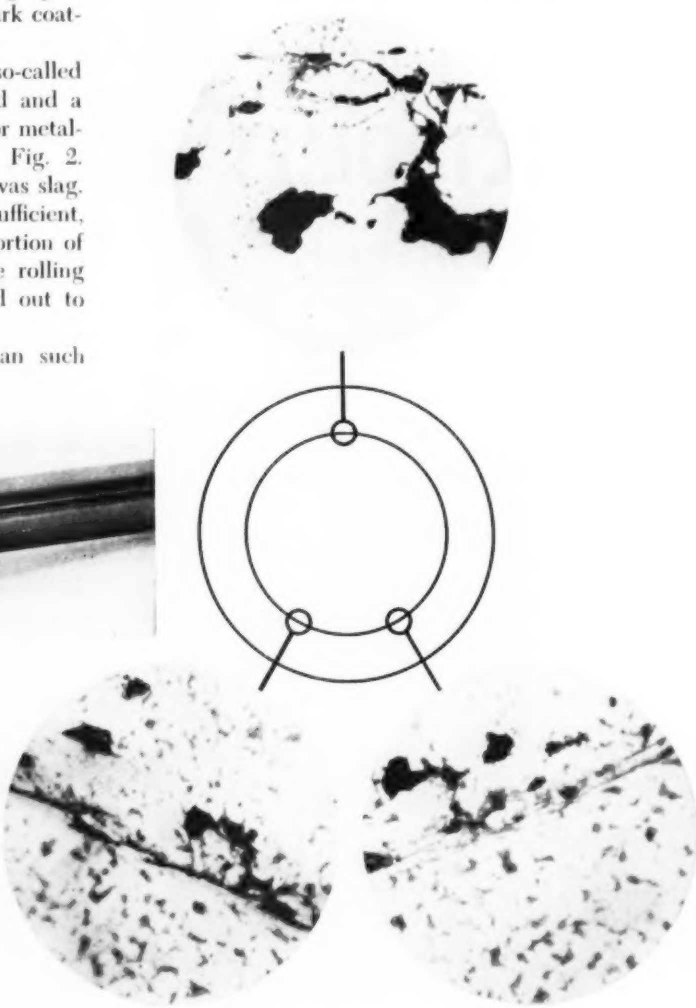


Fig. 2 – Micrographs of Cross Section of the Joined Parts Shown With Respect to Their Location on the Rod. Two bottom micros, at 50× after etching with 2% nital, and the one at top, at 400× and unetched, show nature of slag inclusions

Endurance Limit of Zirconium

LIVERMORE, CALIF.

The properties of zirconium and its alloys are of considerable interest to metallurgists engaged in work pertaining to atomic energy. Whereas many of the properties have been investigated rather thoroughly, little data are available on the fatigue properties. The results of cyclic stress tests at *(Continued on p. 130)*

Correspondence

(*Continued from p. 126*) room temperature are reported here for rotating-beam specimens of crystal-bar zirconium.

The specimens were made from ½-in. diameter bars, purchased from Westinghouse Electric Corp. Typical chemical analysis is:

Si	0.005%	Mn	< 0.001%
Fe	0.02	Mg	< 0.001
Al	0.005	Pb	< 0.001
Hf	0.004	Mo	< 0.001
Cu	0.0007	Ni	0.005
Ti	0.002	Cr	0.003
Ca	0.005	Sn	< 0.001

Tensile properties for two samples were:

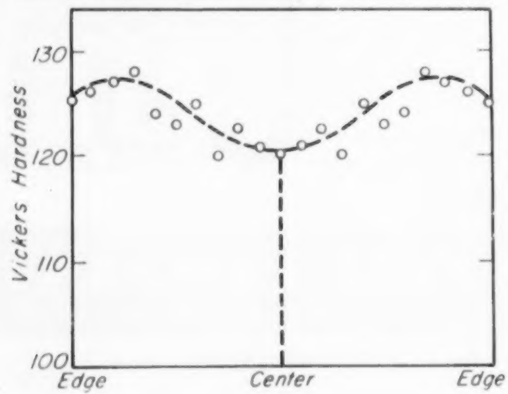
Tensile strength, psi.	52,700	51,000
Yield strength (0.1%), psi.	32,500	31,000
% Elongation in 1 in.	18.0	15.0
% Reduction of area	37.9	42.5
Modulus of elasticity, psi.*	14×10^6	12×10^6

With the exception of the yield strength, which appears to be on the high side, these results conform to published data. Figure 1 shows the extent of the variation in cross-sectional hardness found in the ½-in. diameter bar. Although fabrication history is not known, the somewhat greater hardness on the surface of the bar and the pronounced elongation of the grains indicate some cold working.

The fatigue tests were made on a Krouse stress machine which employs a cantilever-beam load applied to the rotating specimen. All of the tests were made at 8000 rpm. on specimens of the type illustrated in Fig. 2. After machining, the specimens were polished longitudinally to an approximate surface finish of 4 micro-in.

*Difference for Modulus of 11×10^6.

Fig. 1 – Variation in the Cross-Sectional Hardness of ½-In. Diameter Crystal-Bar Zirconium



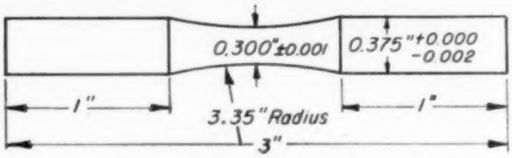


Fig. 2 – Dimensions of Specimens Used for Fatigue Tests

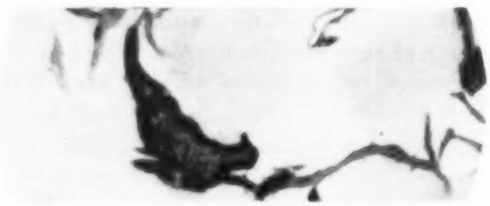
There is some variation in the results at lower values of stress. This may be attributed to the fact that all but one of the samples which were loaded to 26,500 psi. or less broke in the shoulder at the supported end of the cantilever beam. The specimen which was loaded to 16,000 psi. did not break at 101×10^6 cycles. It was observed that crystal bar zirconium does not have a clearly defined endurance limit. The results of the fatigue tests are summarized below. This work was performed under A.E.C. Contract No. AT(11-1)-74.

Stress	Number of Cycles
40,000 psi.	17,200
35,000	62,200
30,000	235,300
29,000	1,811,000
28,000	979,200
26,500	3,795,000
25,000	21,901,100
24,000	18,700,000
23,000	16,736,800
20,000	20,042,000
18,000	59,090,800
16,000	101,740,000*

*Test stopped at this point.

W. P. Wallace and R. H. Wallace
Livermore Research Laboratory
California Research and Development Co.

Bird in the Bush



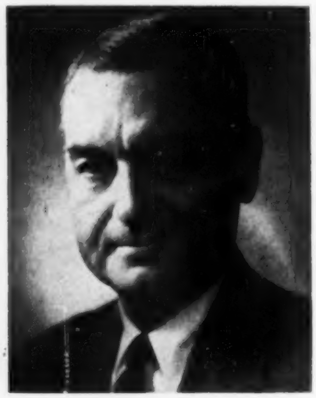
East Hartford, Conn.

I have finally located one of those two proverbial "birds in the bush". This micro is of an A.M.S. 5392 etched with 10% nital at 500×.

John Hutchins
Materials Control Laboratory
Pratt & Whitney Aircraft

Personal Mention

Robert J. Raudebaugh



Adolph O. Schaefer

ROBERT J. RAUDEBAUGH, chairman of the Georgia Chapter and national trustee of the American Society for Metals, has recently accepted a position in the research laboratory of the International Nickel Co. in Bayonne, N. J. From June 1948 to Jan. 1, 1954, Dr. Raudebaugh held the rank of professor in the School of Chemical Engineering at the Georgia Institute of Technology and was in charge of the metallurgy program of the school. In the ten years previous to joining the faculty at Georgia Tech, Dr. Raudebaugh held teaching positions at the University of Rochester (1944-48) and Purdue University (1939-44). While at Purdue, he did graduate work, earning the Ph.D. degree in 1945. Dr. Raudebaugh's affiliation with the International Nickel Co. research laboratory is his second with an industrial research organization. He joined the research laboratory of the American Rolling Mill Co. (now Armco Steel Corp.) in Middletown, Ohio, shortly after graduating from Carnegie Institute of Technology in 1933, and remained until 1939 when he left to enter Purdue. In his new position, Dr. Raudebaugh will direct research on stainless steels and high-temperature alloys. An active ASMember since 1933, he is also the author of "Nonferrous Physical Metallurgy" which was published in 1952.

ADOLPH O. SCHAEFER was recently honored by his alma mater and by the Philadelphia Chapter, . The General Alumni Society of the University of Pennsylvania gave him the Award of Merit at the Founders' Day exercises. The honor was accorded Mr. Schaefer for his many contributions to his company, to industry and to engineering, for his work with the technical societies and for the recognized services to his alma mater in raising of funds, to the Engineering Alumni Society and to the Publications Board. Then at the February meeting, the Philadelphia Chapter hailed him as "Delaware Valley Metals-Man of the Year"—the first citation of this sort made by the Chapter.

Mr. Schaefer, a native of Philadelphia, graduated from the University of Pennsylvania in 1922 with a B. S. degree in chemical engineering, and immediately started work with the Midvale Co. as research metallurgist. He now holds the title of vice-president in charge of engineering and manufacturing. He has an international reputation as an authority on the manufacture of large forgings. He was a member of the U. S. Army Ordnance Metallurgical Advisory Committee in 1939-41, and from 1941 to 1944 was a member of the Gun Committee, and chairman of a group charged with preventing bottlenecks in gun manufacture in all American plants. He served on the War Production Board as a member of the Industry Advisory Committee and the Super Alloys Committee. He also served on the Joint British-American Metallurgical Mission. Mr. Schaefer is a past secretary-treasurer and chairman of the Philadelphia Chapter , and is now a national trustee of the American Society for Metals.

Thomas E. Piper , has been transferred from his former position as chief of process control and reliability of the Convair Guided Missile Division in Pomona, Calif., to director of manufacturing research and development on the staff of the executive vice-president of Consolidated Vultee Aircraft Corp. in San Diego.

Robert O. Johnson , formerly chief service engineer for Consolidated Vacuum Corp. in Rochester, N. Y., a subsidiary of Consolidated Engineering Corp., has been transferred to the Corporation's new location in Palo Alto, Calif., as field representative.

Robert A. Lubker , has been appointed manager of the metals research department at Armour Research Foundation of Illinois Institute of Technology, Chicago. Formerly associate manager of the metals department, Mr. Lubker replaces **Max Hansen** , who resigned to devote full time to revising and translating from the German his textbook on phase diagrams. In his new post, Mr. Lubker heads one of the Foundation's largest research departments. A native of Tacoma, Wash., Mr. Lubker was graduated from the University of Washington in 1942, and received his master's degree in metallurgical engineering at Carnegie Institute of Technology in 1946. He was a nonferrous metallurgist and section manager with Westinghouse Electric Corp., Pittsburgh, from 1942 until he joined the Armour Foundation in 1946.

Robert H. Groman , has been promoted to the position of director of applied welding engineering for Eutectic Welding Alloys Corp., Flushing, N. Y. Mr. Groman was formerly divisional sales manager.

Model #922—Schaible Faucet Assembly with Hydramold Spout. To date more than 1,000,000 Hydramold Spouts have been produced, and not one single failure reported from the field.

Close-up of Schaible Hydramold Machine (Patents Pending): Operation of this machine requires no special skill of the operator. One or any number of workpieces respond to accuracies of a thousandth part of an inch. Wall thickness of spout is uniform, nonporous, without inclusions, seams or joints.

A brass that does not have to be "tailored" to a job, but is made with accuracy in normal mill procedures, meets the unusual material requirements that the Schaible Company has in its remarkable spout fluid forming process called Hydramold.

The Schaible Company, Cincinnati, Ohio, is one of the larger manufacturers of strainers, valves and faucets, who have been more progressive in product design and methods of manufacture. Schaible requirements are exacting as to product quality control. This is especially true of sources of material, and when the company developed, designed and built its four new Hydramold machines to manufacture modern spouts from tubular material, the specifications became most rigid.

This was where the Revere Technical Advisory Staff entered the picture. Revere technical men studied the Hydramold process developed by Schaible engineers, and the unusual forming requirements, thereby helping establish the exacting specifications so that the mill and manufacturer developed mutual material control and process information.

The Schaible Company has made more than one million spouts by this new method without a single field performance failure—better spouts, states Schaible, produced by more economical means than conventional casting methods.

Today, there may be more costly spouts, but according to Schaible "There is no better spout than the Schaible Hydramold formed spout."

This case study is another example of the value of close cooperation between Revere and an exacting customer. The more we know about what you make, and how you make it, the better we can serve you. See the nearest Sales Office.

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Personals

William G. Fricke, Jr. ⊕ is employed as a research metallurgist in the metallography division of the research laboratories of the Aluminum Co. of America, New Kensington, Pa.

Russell Heath ⊕, formerly head of the metallurgical section in the division of industrial research at Washington State College, is now research metallurgist for the Parker Pen Co., Janesville, Wisc.

Luther F. Witmer ⊕ has retired as professor of metallurgy at Lafayette College, Easton, Pa.

Lawrence A. Zeis ⊕, formerly metallurgist with the Nordstrom Valve Division of Rockwell Mfg. Co. in Oakland, Calif., is now metallurgist for Rockwell Valves, Inc., Sulphur Springs, Tex.

Eric Gregory ⊕, a former graduate student of Massachusetts Institute of Technology, has accepted a position with the Manganese Bronze and Brass Co., Ltd., in Ipswich, England.

S. H. Smith ⊕, district manager of the Milwaukee office of the Air Reduction Sales Co., has retired after 38 years of service in the oxyacetylene industry.

John S. Rinehart ⊕, of the U. S. Naval Ordnance Test Station, Inyokern, China Lake, Calif., is spending from 12 to 18 months in England and in Europe to study and do research on the behavior of metals under impulsively applied loads. Dr. Rinehart's work is being sponsored by the Bureau of Ordnance of the U. S. Navy.

George L. Guymon, vice-president and director of sales for Delpark Industrial Filters, has been elected to the board of directors of Industrial Filtration Co., Lebanon, Ind.

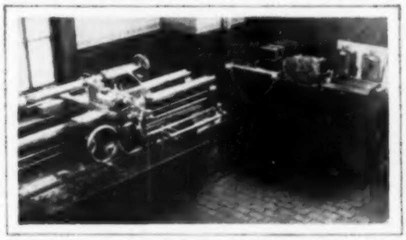
James R. Ireland ⊕, formerly staff assistant to the vice-president in charge of research and engineering of the Indiana Steel Products Co., Valparaiso, Ind., has been appointed assistant director of research. His duties will include the supervision of work under a new contract with the U. S. Air Force for basic and applied research on magnetics.

Now . . . Picture These Advantages for Your Tools and Dies!

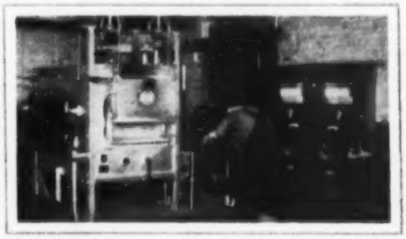
Make this *3-Minute Check* . . . Discover what has been put into a *dependable* die steel to help you get better die performance, lower costs!

Improving existing die steels and developing new ones to meet the need for lower production costs, has been a challenge met by Carpenter. The results are modern die steels that heat treat and machine easier to save time and money; run longer between grinds to reduce unit costs. Here are facts about *Stentor* (Oil-Hard) Die Steel—one of 12 modern steels in Carpenter's well-known Matched Set. Check what *Stentor* offers . . . compare it point by point with the die steel you now use. We believe you'll agree: Here is a real opportunity to put your tooling ahead of competition, take a big step to high quantity output at reduced unit costs.

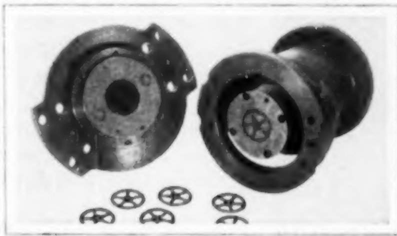
Here is what *Stentor* gives you . . . *COMPARE* it with the die steel *you* use . . .



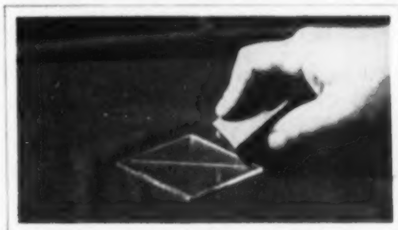
Easy Machinability. Two steels were put through this machining test. One, a well-known oil-hardening tool steel; the other, *Stentor* with its simplified analysis. Bars tested were 3½" rd. with same Brinell hardness and structure. Result: With a cut .020" deep, *Stentor* proved to be 11% easier to machine than the other steel. Does the steel you use provide this *extra economy* in machining?



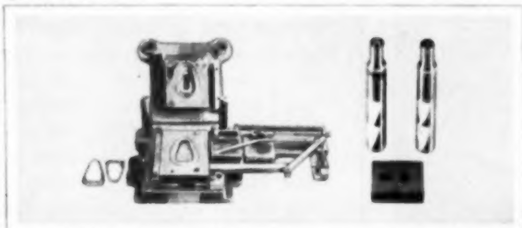
Simplified Heat Treating. Because of *Stentor's* simplified analysis, it hardens from the low temperature of 1420° to 1450°F. This low temperature reduces dangers of size change and decarburization—holds warpage to an absolute minimum. How does the steel you use compare with this?



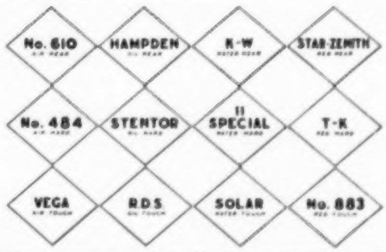
Safety and Accuracy in Hardening. This punch and die blanks 1.342" dia. timing mechanism gears having 120 teeth/90 pitch, made from 24 ga. ¾-hard brass. Customer reports: "In heat treatment the *Stentor* die moved only .0005" on the max. dia. of the gear!" If the oil-hardening steel you use doesn't behave like this, it's time to change to *Stentor!*



Freedom from Decarburization. Here is a *Stentor* part as quenched and before drawing, showing absence of soft skin. This test proves that *Stentor* tools when properly hardened are hard enough, right on the surface, to scratch glass! Does the steel you use give you this *positive* freedom from decarb?



Full Dependability in Service. Here are just two examples of the job *Stentor* does day after day in service. Die on left gave *83 continuous* hours of production between grinds compared to *10 hours* with a chrome-tungsten grade! The ¼" dia. punches shown to right above punch ¼" thick SAE 1020 steel. After *Stentor* was used production went up 160%. How much *more* output could you add to your total with *dependability* like this?



If you are not getting *all* of these advantages from the steel you use, you're missing a big opportunity to cut costs, raise output!

change to Carpenter STEEL

Matched Tool and Die Steels

***. . . modern* die steels engineered to meet *today's* requirements!**

The Carpenter Steel Company, 133 W. Bern St., Reading, Pa.
Export Department: The Carpenter Steel Co., Port Washington, N. Y.—"CARSTEELCO."
Get Immediate Delivery . . . Call your Carpenter Mill-Branch Warehouse, Office or Distributor.

Personals

W. F. Engan, an employee of the Crane Co. since 1910, has retired as manager of the Rochester, N. Y. branch. Mr. Engan had a two-year leave of absence from his job to serve as captain in World War I.

Carl Gustafson has been appointed sales manager of A. Finkl & Sons Co., Chicago.

Fred J. Thomson has been transferred to the York, Pa. plant of the Caterpillar Tractor Co. as heat treat supervisor. Mr. Thomson previously worked at the Peoria, Ill. plant as a heat treat checker.

L. W. Cashdollar has resigned as chief metallurgist of the Union Electric Steel Corp., Pittsburgh, to assume sales duties in the Pittsburgh branch of the Pittsburgh Metallurgical Co., Inc., Niagara Falls, N. Y.

Paul S. Lane has resigned as vice-president of the Muskegon Piston Ring Co., Muskegon, Mich., and is now residing in Miami Shores, Fla., where he expects to establish his own business. Mr. Lane is the author of numerous papers on metallic wear and related subjects.

Anthony Federico, formerly with the metallurgical section of the aircraft laboratory of the White Motor Co., Cleveland, has accepted a position as metallurgical engineer with the research group in the materials laboratory of North American Aviation, Inc., Columbus, Ohio.

Robert J. Teitel has been advanced from associate metallurgist to metallurgist at the Brookhaven National Laboratory, Upton, N. Y.

Jack M. Esten has been appointed to the sales force of the Norton Co., Worcester, Mass., as abrasive engineer, after graduation from the company's sales training course.

Weaver E. Falberg has been appointed assistant general manager of sales of Joseph T. Ryerson & Son, Inc., with headquarters in Chicago. Mr. Falberg was formerly manager of the alloy steel division.

Robert S. Green, chairman of the department of welding engineering at Ohio State University, Columbus, has been named executive director of the university's engineering experiment station. He will remain as head of the department of welding engineering and as part-time professor in that department. Prof. Green has been a member of the engineering teaching staff since 1947, serving first as an assistant professor in industrial engineering. In 1948 he was named as acting chairman of welding engineering, and became chairman and full professor in 1952.

Lynn J. Ebert has been named assistant professor and executive officer of the department of metallurgical engineering at Case Institute of Technology, Cleveland. Mr. Ebert, a senior research associate at Case since 1949 and the author of many published articles, received his B.Sc. and M.Sc. degrees from Case in 1941 and 1943, respectively, and expects to receive the Ph.D. degree at the June 1954 commencement.

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"Step right up Gentlemen, you ain't seen nuttin' yet."

And you haven't until you've seen Northwest's New Liquid Stripper #6 in action.

This high-speed baby really "peels" all organic finishes from steel, magnesium, and zinc die castings in one performance—no two, three, or four run-throughs before the work is ready for re-painting. The closest approach to a universal stripper yet developed.

Liquid Stripper #6 is Safe—no fire hazard, no odor, no fumes, non-toxic.

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Remember — YOUR COST PER FINISHED ARTICLE IS THE TRUE COST OF YOUR CLEANER.

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pioneers in pH cleaning control *serving you since '32*

Personals

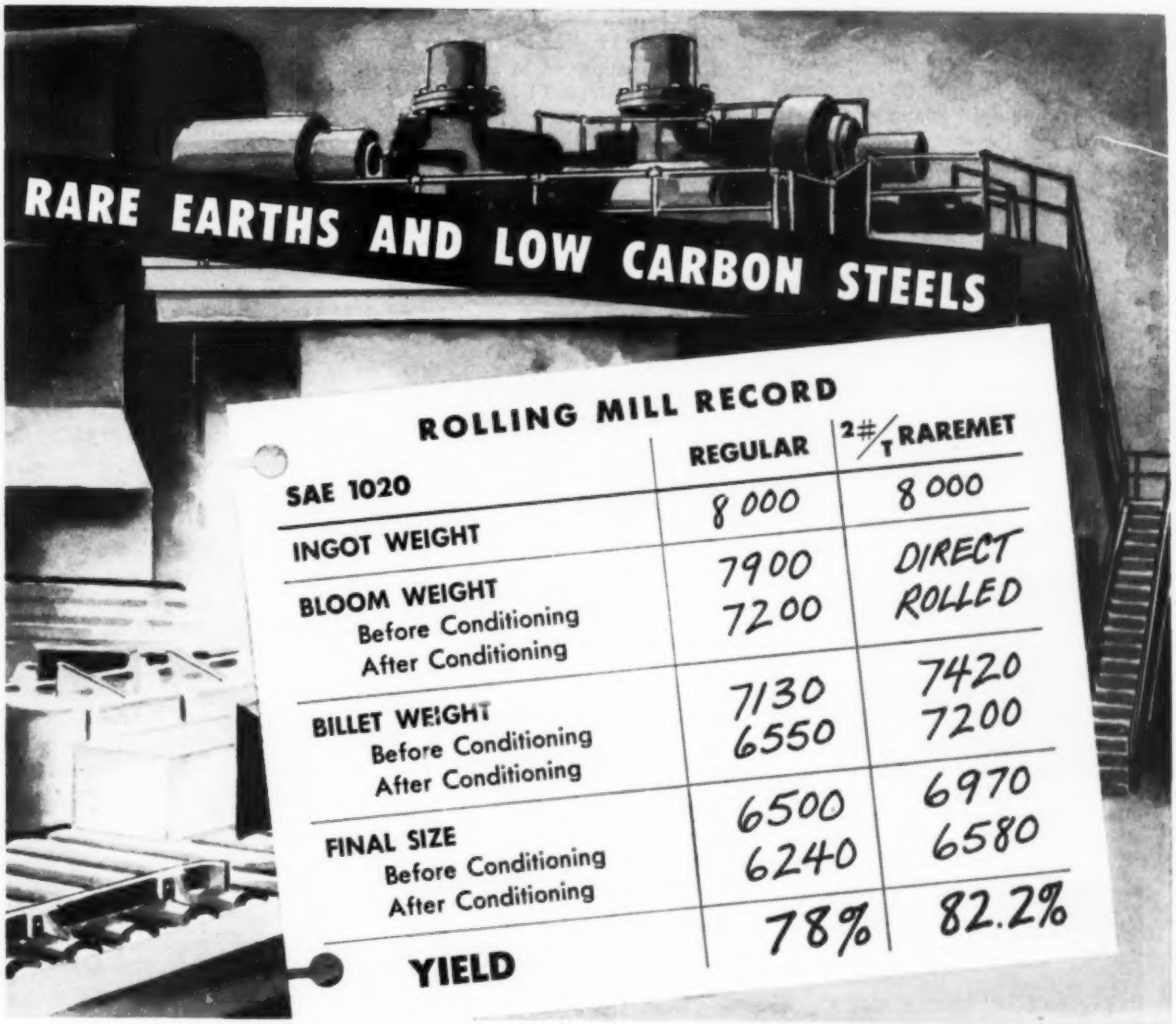
Stanley F. Reiter has resigned from General Electric Co., where he was a research associate in the metallurgy department at Schenectady, to accept an appointment with the Rome Fastener Corp., New Haven, Conn., as technical manager in charge of engineering and research activities.

Arthur A. Burr, associate head of metallurgical engineering at Rensselaer Polytechnic Institute, has been authorized by the Watertown Arsenal Laboratory of the U. S. Army, under extension of contract, to continue his research for the Army until next September. Dr. Burr is studying chromium-nitrogen and chromium-oxygen equilibria for the Watertown Arsenal, and has been engaged in this program of research since July 1952.

Aaron B. Bagsar has retired after 22 years' service with the Sun Oil Co., Philadelphia. Dr. Bagsar joined the company in 1932 as chief metallurgical engineer and served in that capacity up to the time of his retirement. A member of numerous scientific societies and fraternities, he has written a number of papers on subjects within his field, and is also a holder of both U. S. and Canadian patents. He attended the University of California, University of Idaho, and Columbia University, receiving a Ph.D. in metallurgy at the latter. Succeeding to the position vacated by Dr. Bagsar will be **Joseph E. Carney**, who joined the metallurgical department of the company in 1934 and was subsequently named chief inspector. In 1951, Mr. Carney was appointed assistant chief metallurgical engineer, a position he held until his recent promotion.

M. R. Maynard, who was appointed treasurer and general manager of Dominion Aluminum Fabricating, Ltd., Toronto, Ont., when the firm was organized in 1951, is now president and managing director of the company.

Hugh B. Hix has resigned from the Ryan Aeronautical Co., San Diego, Calif., where he was employed as a metallurgist, to return to his former position in the pigments department of E. I. du Pont de Nemours & Co., in Newport, Del.



The troubles of producing low carbon steels have been mainly confined to rolling and surface preparation.

Since production economies are necessary, it's important to know what marked improvements have recently been obtained by Rare Earths in steel production. Minimizing blooming mill cracking, less conditioning time per ton, and increased yields are some of the results already proven. More than 200 production heats of low carbon steel show production savings which alert steel operators can use to advantage.

This recent progress further justifies economical rare earth additions for iron and steel. Commercially known as RareMeT Compound, it is conveniently packaged in ten pound containers.

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Subsidiary: Cleveland Tungsten, Inc., Cleveland — Plants: Washington, Pa., York, Pa.

MCA

Personals

Floyd E. McBride is employed as a metallurgist in the jet research section of the metallurgical department at Thompson Products, Inc., Cleveland.

Carl L. Langenberg has accepted a position as jet engine plant metallurgist at the Oldsmobile Division of General Motors Corp., in Lansing, Mich.

Norman E. Daniel, formerly a student at Virginia Polytechnic Institute, is employed as an engineer at Battelle Memorial Institute, Columbus, Ohio.

Carl L. Sonnenschein is on an industrial leave from the University of California at Los Angeles where he was assistant professor of engineering, and is associated with New Castle (Ind.) Products, Inc., in charge of the research and development program.

John E. Srawley has resigned as research metallurgist at the British Columbia Research Council, University of British Columbia in Vancouver, to accept an appointment as development engineer with the Meehanite Metal Corp., New Rochelle, N. Y. Mr. Srawley was formerly a senior scientific officer at the British Cast Iron Research Association in England.

Frank J. Bascia, formerly employed as materials engineer at the U. S. Naval Underwater Ordnance Station, Newport, R. I., has accepted a position as assistant metallurgist with the Hitchiner Mfg. Co., Milford, N. H.

John C. Ward, who is employed by Jones & Laughlin Steel Corp., Pittsburgh, was recently promoted from metallurgical investigator to service contact metallurgist for strip and sheet products.

Elliot A. Baines, formerly production manager at National Cored Forgings Co. of South Norwalk, Conn., is now employed as sales engineer in the hot forging division, Scovill Mfg. Co., Waterbury, Conn.

John W. Rendall, formerly metallurgist with the Pusey & Jones Corp., Wilmington, Del., is now a sales representative in the Missouri Coke and Chemical Div. of Great Lakes Carbon Corp. with headquarters in St. Louis.

Richard B. Belser, who for some time has held the position of research physicist at the Engineering Experiment Station of Georgia Institute of Technology where he acted as assistant director of a project sponsored by the Signal Corps, has been appointed project director, succeeding to the position left vacant by **Robert J. Raudebaugh**.

Helmut Thielsch, formerly director of applied welding engineering for Eutectic Welding Alloys Corp., Flushing, N. Y., has been appointed metallurgical engineer in the industrial piping division of Grinnel Co., Inc., Providence, R. I. Mr. Thielsch, who was for three years with the Welding Research Council of the Engineering Foundation, will be concerned with the preparation of specifications, approval of materials for welding, metallurgical and welding research, and the preparation of technical reports.

Personals

Franklin L. Obenhaus has accepted a position as mechanical engineer in the machine design section of Carando Machine Works, Stockton, Calif.

Jerome B. Malerich is now employed by General Electric Co. in the Thomson Laboratory, Lynn, Mass.

W. H. Neu has been transferred from Pittsburgh to Cincinnati as district manager for Leeds & Northrup Co. of Philadelphia.

William B. Weber, formerly metallurgical engineer at the Peoria, Ill. plant of Caterpillar Tractor Co., is now supervisor of the metallurgical laboratory for the York, Pa. plant.

Bradley F. Bennett, who was promoted to the rank of captain in the U. S. Navy in October, 1953, is presently assigned to three months' study of hydraulic system hazards on shipboard. Upon completing this study, Captain Bennett expects an assignment as director of the materials development division, Bureau of Ships, Washington, D.C.

Frank H. Sebring is now employed as a metallurgical engineer for Freeport Sulphur Co., Freeport, Texas.

Kenneth Kajola is on a leave of absence from his position as materials engineer at the U. S. Naval Gun Factory in Washington, D.C., and has been inducted into the U. S. Army. At the present time he is receiving individual engineer training at Fort Leonard Wood, Mo.

S. L. Weaver was transferred the first of the year from the Chicago district office as sales engineer to Pittsburgh as district manager of sales for the Latrobe Steel Co.

James E. Reynolds has completed the requirements for a D.Sc. degree in metallurgical engineering at the Massachusetts Institute of Technology, and has accepted a position as principal metallurgist at Battelle Memorial Institute, Columbus, Ohio.

W. J. Lawler has been made technical superintendent of the Trentwood, Wash. works of the Kaiser Aluminum & Chemical Corp.

Personals

James E. Fifield, formerly metallurgist with the New England technical section of the International Nickel Co., Inc., is now vice-president and general manager of the Ductile Iron Foundry, Stratford, Conn.

Bernard Hammer has joined Acro Steel Treating Corp., Hammond, Ind., as chief metallurgist, and **Carl Wilkins** has been appointed general superintendent of the firm.

Roy J. Dunham, formerly Michigan district manager of the Heatbath Corp. of Springfield, Mass., is now an associate member of the J. E. Bullock Co., Detroit.

James M. Lommel, graduate student in metallurgical engineering at Illinois Institute of Technology, Chicago, has been awarded top honors by the American Institute of Mining and Metallurgical Engineers for a paper submitted in its twelfth annual contest. Mr. Lommel, who is studying at Illinois Tech, on a fellowship provided by Allegheny Ludlum Steel Corp., expects to receive his master's degree in June.

Gary Steven has been appointed senior metallurgist at Armour Research Foundation of the Illinois Institute of Technology, Chicago. A native of Vienna, Austria, Mr. Steven was graduated from the Massachusetts Institute of Technology in 1940, and holds Master's degrees in mechanical engineering and metallurgical engineering from the University of Pennsylvania and Illinois Institute of Technology, respectively. He joined Armour Research Foundation in 1948.

H. G. Thompson is now quality control manager for the Murray Ohio Mfg. Co., Cleveland, after five years as director of quality control with the Master Electric Co. in Dayton, Ohio.

L. D. Richardson, formerly divisional sales manager for the Eutectic Welding Alloys Corp., Flushing, N. Y., has been promoted to national supervisor of sales and service. In addition, Mr. Richardson will serve as general sales supervisor for the Dominion of Canada, maintaining his headquarters in Detroit.

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Low Cost Degreasing

with maximum safety...

Nialk® TRICHLORethylene

Here's a chlorinated organic solvent that removes from metal parts virtually every kind of foreign matter—waxes, oils, greases, gums, tars, chips. And at lowest possible cost—because it:

CUTS POWER CONSUMPTION . . . the specific heat of Nialk TRICHLORethylene is less than ¼ that of water.

CUTS VAPOR LOSS . . . its vapor density is 4.5 times that of air.

COSTS YOU NOTHING EXTRA . . . we have never charged a premium price for Nialk TRICHLORethylene.

Equally important, Nialk TRICHLORethylene is fast, thorough, safe. Its low boiling range (86.6°-87.8°C, based on standard ASTM tests) permits vaporization at low steam pressure. Its low viscosity (0.58 centipoises at 20°C) and low surface tension (about 29 dynes per cm at 30°C) give rapid wetting of surfaces, plus thorough diffusion into pores and relatively inaccessible openings. It has no flash point and no fire point, is classed as nonflammable at room temperature and only moderately flammable at higher temperatures.

You will find, too, that Nialk TRICHLORethylene is stable and completely re-usable after distillation.

In short, Nialk TRICHLORethylene is an ideal solvent for almost any metal degreasing application. Quickly, safely, economically, it leaves parts clean, warm and dry, ready for immediate assembly, inspection or surface treatment. Order now. Delivery will be made promptly.

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Standard motor driven Spencer Turbos are listed in more than 160 sizes. For special applications, there are many variations, six of which are illustrated.
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With universal motor, 35 to 75 cfm at 12 to 40 oz. pressure
GAS BOOSTER
For handling gas, acid fumes, poisonous, corrosive or explosive gases
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Overhang or outboard type for coupled drive
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For odd frequency or other than electric motor driven
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Personals

Pascal Levesque, formerly engineer-in-charge of the engineering laboratories of Slyvania Electric Products., Inc., is now associated with the research division of Raytheon Mfg. Co., Waltham, Mass., as consulting metallurgist in semiconductors, ferrites and ultrasonics.

J. Roger O'Hara has completed the rotating engineering program with General Electric Co. and has accepted permanent placement in the Carboloy Dept. in Detroit.

Emanuel Gordon, chief metallurgical engineer for Metal Hydrides, Inc., Beverly, Mass., will head the company's new metallurgical development department.

J. M. Weldon has been transferred to the general sales department of the International Nickel Co., Inc., as assistant to the vice-president. Mr. Weldon, in his new position, will deal principally with the company's mill and foundry products. Associated with International Nickel since 1927, he has held various assignments in the sales, executive and other departments.

Paul Schwarzkopf, president of American Electro Metal Corp., Yonkers, N. Y., has been elected vice-president and a member of the board of directors of the recently formed Borolite Corp., Niagara Falls, N. Y. **Frank W. Glaser**, newly elected vice-president of American Electro Metal Corp., is also a director of the new company.

Harold C. Templeton, who formerly served as assistant metallurgist at Lebanon Steel Foundry, Lebanon, Pa., has been appointed chief metallurgist. Mr. Templeton is a graduate of the Colorado School of Mines, and prior to his present connection was with the Babcock & Wilcox Co.

Leslie Clifton Whitney has been appointed manager of development engineering at Copperweld Steel Co., Pittsburgh, after serving the company as chief metallurgist since 1930. His new duties will include process and product development, as well as quality control. Mr. Whitney graduated from Lehigh University with a degree in metallurgical engineering, and is a past chairman of the Pittsburgh Chapter.

Personals

Elry Christensen has been appointed sales manager for Michigan Steel Casting Co., Detroit.

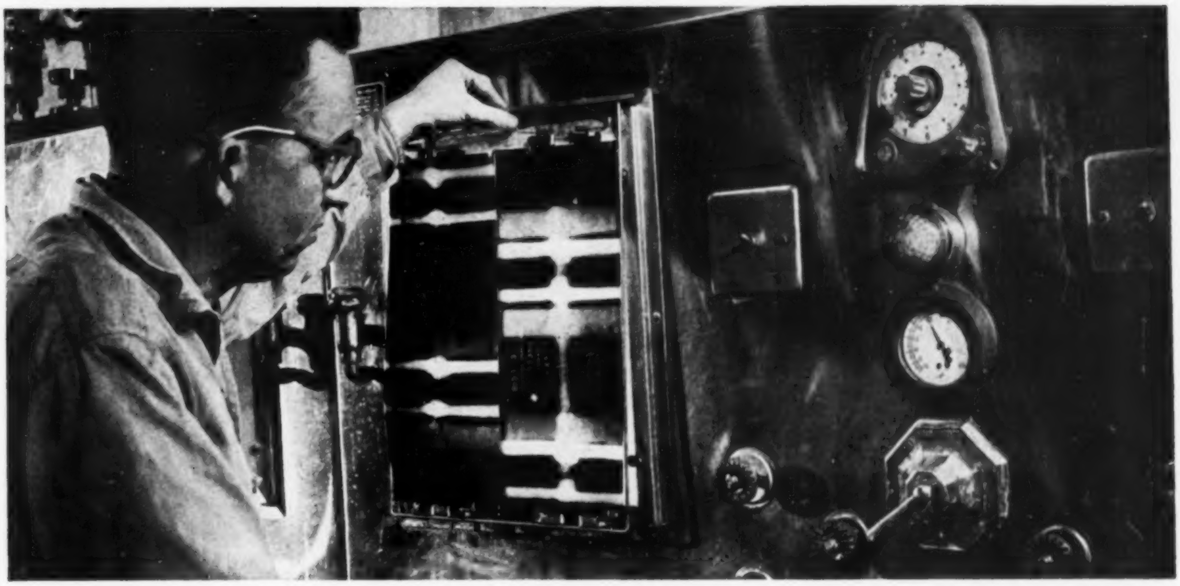
A. D. Arnaut has joined the New York sales force of the Wall Colmonoy Corp. of Detroit as sales engineer. Mr. Arnaut is a metallurgical engineering graduate of the University of Wisconsin. Following postgraduate work at the Polytechnic Institute of Brooklyn and Massachusetts Institute of Technology, he was a research engineer for Sylvania Electric Co., and immediately prior to his present connection was assistant sales manager in the New York office of the Denver Equipment Co.

William Adam, Jr. was elected president of the Ajax Electric Co., Inc., Philadelphia, after **G. H. Clamer** announced his desire to retire from that office. **John E. Haig** and **Leon B. Rosseau** were elected vice-presidents. Dr. Clamer will continue as president of Ajax Electro Metallurgical Corp., Ajax Electrothermic Corp. and Ajax Engineering Corp.

H. R. Hanley has gone to the Orient for a year or more to organize a department of nonferrous metallurgy in the University of Taiwan in Formosa. Dr. Hanley is a graduate of Missouri School of Mines and Metallurgy, and in 1923 he returned to his alma mater to become associated with the metallurgical engineering department, later serving as head of the department for several years. Although officially retired. Dr. Hanley has continued to do some teaching and has carried on an extensive research program in various fields of metallurgy.

G. H. Hille has been appointed director of purchases of Salem-Brosius, Inc., Salem, Ohio. Mr. Hille, formerly with the purchasing division of Ladish Co., Cudahy, Wis., will supervise all purchasing functions of the company.

Thomas H. Jeffers has been appointed assistant general manager of the Anaheim, Calif. division of the Robertshaw-Fulton Controls Co. and has also been elected assistant vice-president of the company. Mr. Jeffers was formerly chief engineer at the Anaheim division.



Mr. Campbell checking furnace-muffle radiograph made on Du Pont Type 506 Film. Says, "We're sure of consistent density on every job."

"Du Pont X-ray Films meet every demand we make of them,"

States Mr. George R. Campbell, Chief Radiographer, Elyria, Ohio, Plant of American Brake Shoe Co. (Electro-Alloys Division)

Since 1935, Du Pont X-ray Films have helped inspection work at the Elyria, Ohio, plant of the American Brake Shoe Company. In testing nickel-chrome castings for heat-treating furnaces and abrasive equipment, the shop uses Type 504 for regular, and Type 506 for rigid-tolerance jobs. According to George R. Campbell, Chief Radiographer, these films have measured up . . . they help simplify work in his department.

"Du Pont X-ray Films meet every demand we make of them," he continued. "In our operation, we use two x-ray units and average about 800 radiographs a week. It's extremely important that we get consistent image density . . . particularly since we handle a great amount of similar work for clients. Density of image must be the same from day to day, as comparisons are frequently made, and it's difficult to read radiographs when densities vary. Consistent film density is the biggest reason why we use Du Pont X-ray Film.

Asst. Radiographer Bernard J. Lowery adjusts holder containing "506" before it is moved into position inside the muffle.

"This film lies flat, too. Doesn't curl when removed from hangers, and we like the way it's packed. Service is another point. Whenever we've had a problem, a Du Pont representative has been on the job in a hurry. Same with deliveries whenever we need film."

Today, Du Pont Types 504, 506, and 510 Films meet the varied needs of industrial radiographers throughout the country. All are rugged, with wide exposure latitude. They're available in all standard sizes. Specify Du Pont X-ray Films when next you order. And for technical help on any x-ray inspection problem, contact your Du Pont representative or write: E. I. du Pont de Nemours & Co. (Inc.), Photo Products Department, Wilmington 98, Delaware. *In Canada: Canadian Industries, Ltd.*

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Personals

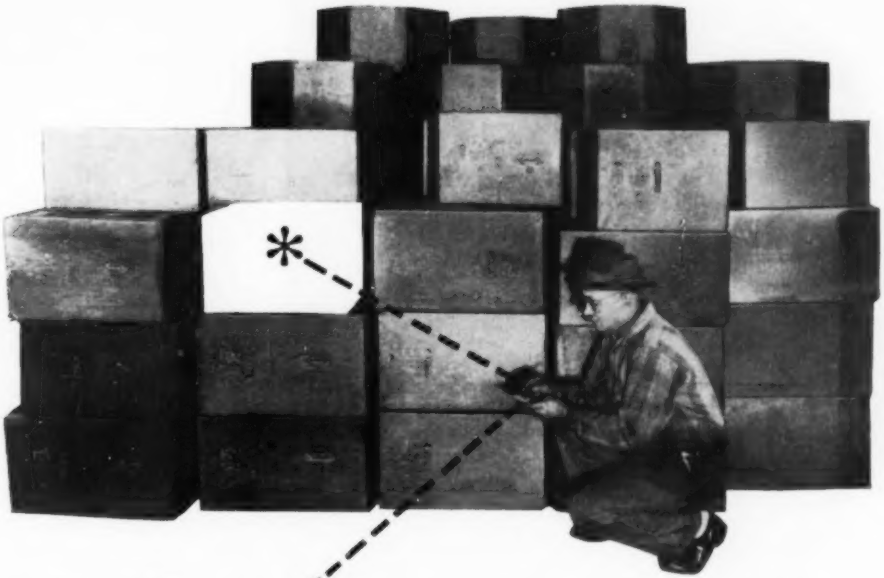
Robert L. Larson has been appointed manager of the alloy steel division of Joseph T. Ryerson & Son, Inc., Chicago. In his new position he has responsibility for coordinating alloy steel sales and related activities at the nation-wide group of 16 Ryerson steel plants. Mr. Larson started with the company at Milwaukee in 1945. In 1946 he became a representative of the alloy steel department in the Chicago area, and in 1950 was named manager of alloy steel sales, Chicago plant, a position he held until his recent promotion.

Robert J. Johnson has joined the Pittsburgh technical section of the development and research division of the International Nickel Co., Inc. A graduate in metallurgy of Pennsylvania State University, Mr. Johnson prior to his present appointment was chief metallurgist with the Round Chain Companies, Cleveland. Previously he had been with Republic Steel Corp., Massillon, Ohio, serving in the metallurgical research laboratory, and also as plant maintenance metallurgist for two integrated steel plants at Canton and Massillon, Ohio.

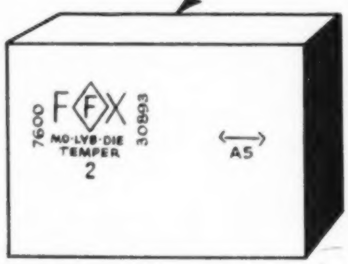
Adolph J. Lena has been appointed associate director of research at Allegheny Ludlum Steel Corp., Pittsburgh, in charge of the physical metallurgy section of the research department. He was formerly research metallurgist. Dr. Lena is a graduate of Carnegie Institute of Technology, taking his undergraduate work at Pennsylvania State College, and was granted the first Allegheny Ludlum graduate fellowship in metallurgy in 1949.

Richard E. Miller, general manager of the Columbus, Ohio plant of Rockwell Mfg. Co., has been appointed to the newly created position of product sales manager in charge of all saws and expendable tools sold by the Delta Power Tool Division.

Otmar C. Miller has been appointed to the position of sales engineer for the steel and tube division of the Timken Roller Bearing Co., Canton, Ohio, with headquarters in Chicago. Mr. Miller has been with Timken since 1935, for the past ten years as a service metallurgist.



Finkl Die Blocks have your number



The entire history of a Finkl die block is hot stamped on its side. For instance, #7600 is the heat or melt number used to fill the order. #30893 is the production number. The FX and Diamond F is the trademark of the special steel used. Temper 2 signifies the hardness to which the block is heat treated. The arrow shows the direction flow of the metal as a guide for die sinking. The A5 under the arrow indicates the block location in the ingot runout.

All of this means that we process our forgings and die blocks according to the requirements of you, our customer, with a complete file checking each step from molten steel to finished product. It also means that when you receive a Finkl forging or die block it can be used with confidence. It will do your job and do it well. When you need quality and service specify Finkl forgings and die blocks.

For technical assistance or further information concerning your forging problems, call or write your nearest Finkl District Office.

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Personals

Ernest F. Nippes, head of welding research at Rensselaer Polytechnic Institute, has been authorized by the Wright Air Development Center of the Wright-Patterson Air Force Base, Dayton, Ohio, to continue until next September a program of research he undertook for the Center in July 1952. Dr. Nippes and his associates are making studies and experimental investigations into the flash welding of alloy steels.

Victor E. Reuter, formerly sales representative for the Ackerlind Steel Co. of New York, has resigned, and is now employed as sales engineer for the Electro Arc Sales Co., Ann Arbor, Mich., with headquarters in Brooklyn, N. Y.

Garth S. Thompson has been appointed president and general manager of Misco Fabricators, Inc., Detroit.

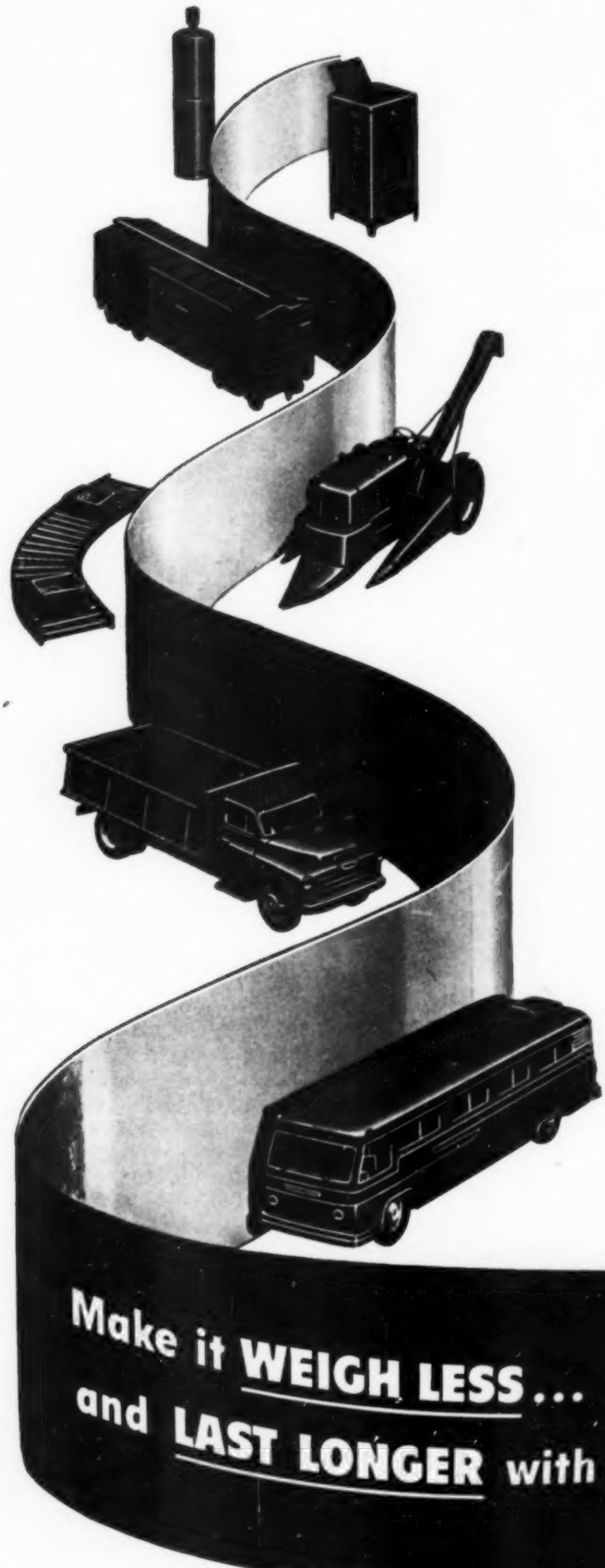
Carl F. Haertel, formerly general foundry superintendent of the Falk Corp., Milwaukee, has assumed new duties as divisional works manager of the foundry and weld shop. Mr. Haertel began his career in the Falk foundry in 1919.

T. W. Whiting, formerly chief metallurgist in the Midlands Division of Guest, Keen & Nettlefolds, Ltd., Birmingham, England, has been appointed metallurgical engineer to the Royal Canadian Navy at Ottawa. Mr. Whiting's official title is coordinator of basic material practices in the Directorate of Engineering Standards and Naval Specifications.

B. W. Depew and **R. E. Wright** have formed the Heat Engineering and Supply Co. with headquarters at Monrovia, Calif. Mr. Depew is a past chairman of the Golden Gate Chapter at San Francisco, and Mr. Wright was active in the Cleveland Chapter before his recent move to California.

Daniel A. Perednia has accepted a position as process engineer with the electronics division of the Gabriel Co. in Norwood, Mass.

Philip C. Miller is now performing the duties of project supervisor in the heat resistant materials group, metallurgical division, Navy Air Experimental Station, Philadelphia.



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It has high fatigue life with great toughness.
It has greater resistance to abrasion or wear.
It is readily and easily welded by any process.
It polishes to a high lustre at minimum cost.

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N·A·X

HIGH-TENSILE STEEL

Cleaning Steel . . .

(Starts on p. 123)

cone is at least eight times the port diameter, and the flame impinges the surface at an angle of $60^\circ \pm 15^\circ$. The torch should be moved at such speed that the surface is dehydrated, and dirt, rust, unbonded mill scale, scale in the form of blisters or scabs, and similar foreign matter are freed by the rapid, intense heating of the flames. Rusted areas need to be treated long enough so that all flakes of rust or rust-scale are removed and the surface of the red granulated rust is reduced to a black powder. On the other hand, overheating can cause unbonded scale or other foreign matter to fuse to the surface of the steel, or warp thin sections of steel.

PICKLING

The purpose of pickling is to remove completely all mill scale, rust, and rust-scale by chemical reaction, or by electrolysis, or by both. First, heavy deposits of oil, grease, soil, drawing compounds, and foreign matter other than rust, scale, or oxide are completely removed by solvent cleaning. Small quantities of such foreign matter may be removed in the pickling tanks, provided no detrimental residue remains on the surface. After this procedure, the mill scale, rust-scale, rust, and oxide may be removed by any of the following methods:

1. Pickling in hot or cold solutions of sulphuric, hydrochloric, or phosphoric acid to which sufficient inhibitor has been added to minimize attack on the base metal, followed by adequate rinsing in hot water above 140° F.

2. Pickling in 5 to 10% (by weight) sulphuric acid containing an inhibitor, at a minimum of 140° F., until all rust and scale are removed. This is followed by thorough rinsing in clean water, then immersion for 3 to 5 min. in about 2% (by weight) phosphoric acid which contains about 0.3 to 0.5% iron phosphate and is held at about 180° F.

3. Pickling in 5% (by volume) sulphuric acid at 170 to 180° F. (with sufficient inhibitor added to minimize attack on the base metal) until all rust and scale are removed. This is followed by a 2-min. rinse

(Continued on p. 156)

The answer to most of your questions about stainless steels are right at your finger tips, when you use Crucible's unique new Stainless Steel Selector.

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REX HIGH SPEED • TOOL • REZISTAL STAINLESS • MAX-EL • ALLOY • SPECIAL PURPOSE STEELS

Cleaning Steel • • •

(*Starts on p. 123*)

in water at 170 to 180° F. The steel is then immersed for at least 2 min. in a hot, inhibitive solution maintained above 190° F. and containing about 0.75% sodium dichromate and about 0.5% orthophosphoric acid.

4. Electrolytic pickling in an acid or an alkaline bath using alternating or direct current. If the work is made the cathode (when direct current is used), hydrogen embrittlement must be prevented or minimized by adequate treatment. Electrolytic pickling that is carried out in an alkaline bath must be followed by a thorough rinse in hot water; then by a dip in a dilute solution of phosphoric acid, chromic acid, or solution of dichromate until no trace of alkali remains on the surface.

The dissolved iron content should not be permitted to exceed 6% in sulphuric acid baths, or 10% in hydrochloric acid baths. It is necessary that the rinse tanks be supplied continuously with fresh water; also the total amount of acid or dissolved salts (due to carry-over) in the tanks should not exceed 2 g. per 1. (0.2% by weight).

Carry-over can be minimized by holding the steel briefly over the acid tank from which it has been withdrawn so as to allow the major porton of the acid to drain.

Recrystallization in Aluminum Alloys*

RECRYSTALLIZED grain size in wrought aluminum and its alloys reflects the previous history of initial grain size, degree of cold deformation and annealing temperature. As a result of observations by numerous workers, these factors have been summarized into four empirical rules:

1. The recrystallized grain size of a cold worked metal decreases as the amount of deformation is increased and is substantially independent of the annealing temperature.

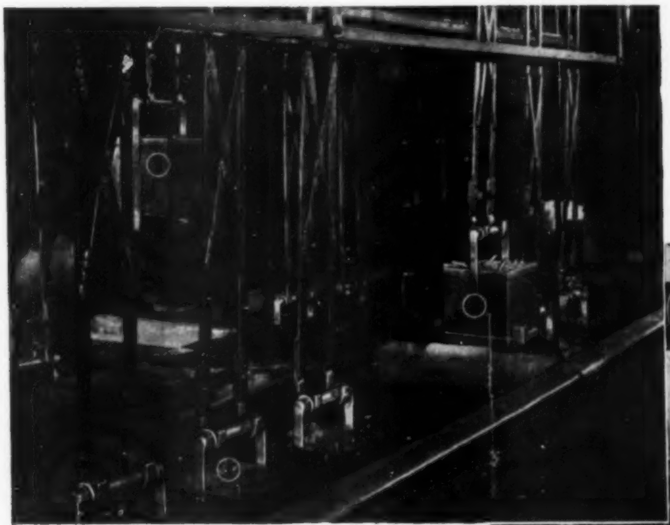
2. With a given annealing temperature, there is a critical strain be-

(*Continued on p. 158*)

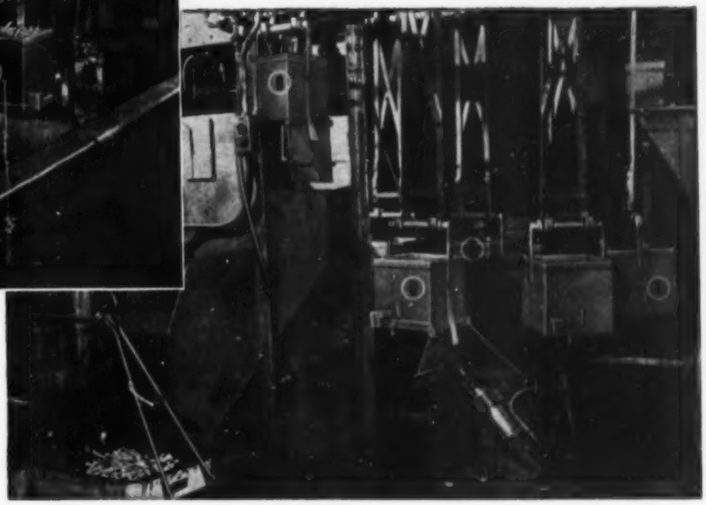
*Digest of "Critical-Strain Effects in Cold-Worked Wrought Aluminium and Its Alloys," by W. M. Williams and R. Eborall, *Journal* of the Institute of Metals, Vol. 81, 1952-53.

ROLOCK

FABRICATED HEAT AND CORROSION RESISTANT ALLOYS



GREATER PRODUCTION *thru an* AUTOMATIC PICKLE-WASH CYCLE *for* Valve Stems *at* A. SCHRADER'S SON



Shown in the two photographs are start-to-finish steps of an automatic oval travel cycle for bright dips and washes of Schrader brass valve stems. The baskets (9" x 9" x 9") were made by Rolock from 18-8 stainless steel to carry 75-lb. loads. This system replaced hand pickling and has greatly increased production, lowered hour costs considerably.

Basket No. 1 is hopper loaded . . . Nos. 2, 3, 4, 5 show progressive positions thru tanks. At No. 6, bottom latch of basket has been automatically tripped, releasing load thru a chute to carrier . . . and at No. 7, bottom is closed by an air gun and is ready for reloading. Some baskets have been in use for 9 years.

This is a typical example of Rolock cost-reducing equipment for handling metal parts thru finishing operations . . . either heat or corrosion resistant baskets, crates, trays, retorts, muffles, tanks, sinks, etc.

Whatever your requirements,

SEND FOR CATALOGS B-8 (Heat Treating) or B-9 (Corrosion Resistant).

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6RL53A

Recrystallization . . .

(Continued from p. 156)

low which complete recrystallization does not occur. This critical strain is responsible for the largest grains after annealing.

3. The critical strain is higher with lower annealing temperature.

4. For a given annealing temperature, the critical strain is higher, the larger the initial grain size of the material and, because the recrystallized grain size is mainly dependent on the strain, the maximum grain size which can be produced by the given annealing treatment is smaller for initially coarse material than for fine-grained materials.

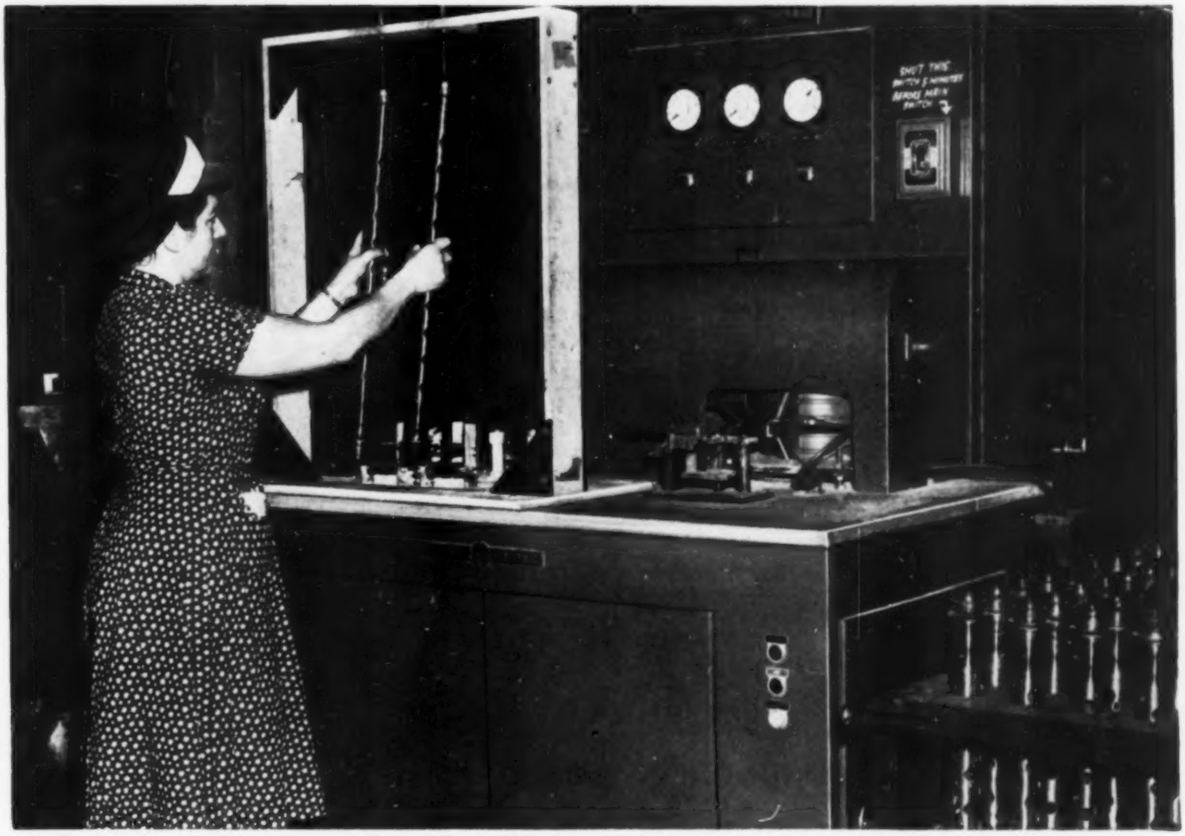
In the present work, recrystallization behavior, with particular reference to critical strains and the coarse grains associated with them, has been studied for super-purity aluminum, commercial aluminum of 99.35% purity, and the commercial aluminum alloys of 2% magnesium and 0.5% manganese, 1% manganese and 1% silicon, duralumin (17 S type), and 1.25% manganese (3 S type).

A range of initial grain sizes in super-purity metal was obtained by annealing at various temperatures between 570 and 930° F. where coalescence readily takes place. The method employed for the alloys was to anneal at different temperatures or to combine the anneal with varied amounts of cold work introduced either by rolling or stretching.

Critical strain was taken to be the strain at the junction between recrystallized and unrecrystallized parts of the gage length, the exact point being that beyond which none of the original structure was retained.

The study revealed that all the materials behaved similarly (differences being only in numerical values) and that the results generally confirmed the empirical rules. With respect to rule 1, it was shown that temperature of recrystallization does have a slight effect, because the final grain size generally was finer with higher temperatures. Rules 2 and 3 were confirmed, but rule 4 requires qualification for it was found that the recrystallized grain size for a given deformation and annealing temperature may depend on initial grain size. This was especially so with super-purity metal and for small

(Continued on p. 160)



COMPACT G-E HEATERS FOR BRAZING FIT PERFECTLY INTO NEW STRAIGHT-LINE PRODUCTION SETUP AT THE SACO-LOWELL SHOPS.

Rejects Eliminated in Gun-jacket Assembly

Saco-Lowell Shops speeds production, cuts costs with G-E Induction Heaters

"In planning our machine-gun production program, we find G-E induction heaters assure us the high-quality brazing necessary to meet strict Ordnance Department requirements," say the metallurgists at the Edwards Plant, Saco-Lowell Shops, Saco, Maine.

At Saco-Lowell, brazing rejects are a thing of the past. Only spot checks are necessary for product inspection, because G-E heaters provide a strong, uniform braze time after time. Saco-Lowell saves on operator training too, because use of these semi-automatic G-E heaters is mastered easily in a few hours.

To learn how you can profitably apply induction heat to your metal processing—in brazing, forging, hardening, or annealing—contact your nearest G-E Apparatus Sales representative today. And write now for new, modern-metal-processing bulletin GEA-5889 on furnace and induction brazing to General Electric Company, Section 720-122, Schenectady 5, N. Y.

GENERAL ELECTRIC

SELECTIVE HEAT produces this clean, strong bond of bearing breach to barrel jacket. Sixty such joints are brazed per hour.

Recrystallization • • •

(*Continued from p. 158*)

deformation because at high temperatures the maximum grain size obtained by critical strain increased with the initial grain size instead of decreasing as predicted. The first part of the rule remained true in practically all cases.

The dependence of final grain size on the initial grain size presumably arises from the fact that during recrystallization after low strains, nuclei form preferentially at structural discontinuities and especially at grain boundaries. In fine-grained material the grain boundary area is larger and more nuclei will be formed in any given conditions than in coarse-grained. For higher strains, nucleation also takes place within the grains, so that the difference in grain boundary area has a less marked effect and the final grain size becomes progressively less dependent on the initial grain size. The strong dependence observed in super-purity aluminum, compared with that in other alloys, is no doubt largely due to the comparatively low critical strains for a given grain size, which make observations possible in a strain range which does not occur in other materials. However, the difference does not appear to be completely accounted for in this way, and there may be other factors operative, such as the possible effect of minor constituents or dissolved elements in promoting nucleation within the grains relative to nucleation at the grain boundary.

It has not been possible to generalize on the effects of alloying on recrystallized grain size, although it has been observed that composition has a striking effect on the value for critical strain. For example, materials of comparable grain size which were annealed at the same temperature showed a variation of 3 to 40% in critical strain value. As might be expected, super-purity aluminum had the lowest critical strain whereas impurities and alloying elements have, in general, the effect of raising critical strain. Manganese appears to be most effective and magnesium the least. If a homogenizing treatment was introduced before hot rolling, the critical strain for the manganese alloy was greatly reduced.

G. M. Young

WAUKESHA CORROSION-RESISTANT ALLOYS

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WAUKESHA 347
(Columbium Stabilized)
STAINLESS STEEL

Tough, highly resistant to corrosion and to extremely high temperatures, WAUKESHA'S No. 347 Columbium Stabilized Stainless Steel may be vitally important in improving your product. You may benefit by using it in valves, pressure fittings, parts in large weldments difficult or impossible to heat treat — or other parts subject to high temperatures (over 800°F.) either in production or in end use.

WAUKESHA No. 347 Columbium Stabilized can be welded successfully without heat treatment, and without impairing its high corrosion-resistant characteristics.

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WAUKESHA maintains a laboratory completely equipped for all metallurgical tests. Every step of production and all materials are under the strict control of the laboratory director and staff . . . and it is through the intensive and extensive research conducted by this laboratory that WAUKESHA is one of a very few foundries that can cast such difficult stainless steel as 321 (titanium stabilized) and columbium stabilized 347.

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Tool Steel Topics

BETHLEHEM STEEL COMPANY, BETHLEHEM, PA.

On the Pacific Coast Bethlehem products are sold by Bethlehem Pacific Coast Steel Corporation. Export Distributor: Bethlehem Steel Export Corporation

BETHLEHEM TOOL STEEL ENGINEER SAYS:

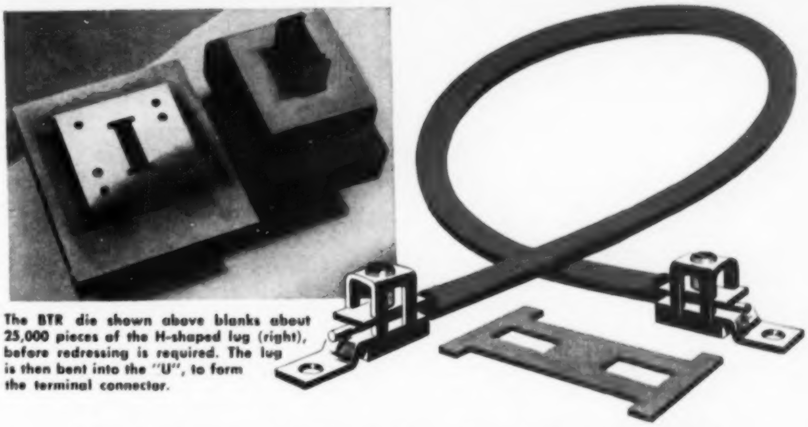
Be Sure to Heat Tools Uniformly

It has always been widely recommended that tools be heated uniformly to the hardening temperature. Unfortunately, this practice is seldom followed.

Absolute uniformity is impossible, as the outer surfaces of a tool must be heated before the interior. The uniformity of heating which results when a tool of constant cross-section is heated, by first preheating and then transferring to a furnace operating at the hardening temperature, is generally satisfactory.

However, when a tool of varying section is encountered (for example 1 in. at one end, and 3 in. at the other end), uniformity of heating cannot be attained by heating in open furnaces. What's the answer? Simply pack the tool in cast-iron chips in a container. Heating through the chips occurs so slowly that the tool can be heated uniformly regardless of section variations.

This procedure can be followed with most types of tool steels — with one exception. With high-speed steels, cast-iron chips cannot be used because the cast iron melts at the temperatures used in heat-treating high-speed steels.



The BTR die shown above blanks about 25,000 pieces of the H-shaped lug (right), before redressing is required. The lug is then bent into the "U", to form the terminal connector.

BTR DIE BLANKS 25,000 LUGS FROM STRIP STEEL BETWEEN GRINDS

One of the parts produced by Pelham Electric Manufacturing Corp., Erie, Pa., is a solderless U-shaped lug, for use on panelboards and switchboards. The lug is blanked from hot-rolled strip steel, ⅛ in. thick. Engineers at the Pelham plant selected BTR for the die, and they've had every reason to be pleased with its performance.

The die, operating in a 25-ton press, has a Rockwell C hardness of 60-62. It's economical, because it produces 25,000 pieces between grinds, with only .008 in. to .010 in. removed in redressing. And it is standing up well on both counts — good wear-resistance and good shock-resistance.

BTR is our general-purpose oil-hardening tool steel of the manganese-chromium-tungsten-vanadium type. In addition to being resistant to wear and shock, BTR has a good reputation for low distortion, and for ease of machining and heat-treatment.

BTR — TYPICAL ANALYSIS

Carbon	0.90	Chromium	0.50
Manganese	1.20	Vanadium	0.20
Tungsten	0.50		

BTR combines abrasion-resistance and toughness, making it suitable for a wide variety of tool-and-die applications.

• • • • • • • • •

Big Babies Turn Out Shell Discs

This huge multiple punch-and-die set blanks 90-mm shell discs, 8⅞ in. in diameter, from .690 gage, C-1030 plate steel. The punches and dies are made of A-H5 tool steel, hardened to Rockwell C 50 to 55. They turn out about 4,500 pieces in an 8-hour turn, and require but a minimum of redressing. A-H5, our 5 pct chrome, air-hardening steel, is well known for durability, minimum distortion in heat-treatment and easy machining.

Rolling Mill . . .

(Starts on p. 121)

In the latter use, the original back-up rolls thus become the work rolls in the two-high arrangement. Occasionally, strip rolling tests may be made with only one small work roll inserted between the two large rolls, the mill thus functioning as a three-high unit. Provision has been made for such an arrangement, the strip being reduced between the middle "baby" roll and the large bottom roll. For this set-up, the universal spindle between the pinion stand and the upper roll is removed and the mill receives its drive solely through the lower universal spindle connected to the bottom roll.

The important advantages to be gained from the four-high configuration in flat rolling were realized as early as 1746 when Polhem was rolling sheets on a mill in which each of the work rolls was supported by a backing roll of larger diameter. Probably the earliest patent in this field was granted to McCleane in 1870 for a four-high mill, in which the work rolls already were offset toward the entry side.

The object of all forms of backed-up rolling mills is to obtain the largest practical reduction in the diameter of the work rolls. Extensive research into the cold rolling of strip has established that – for a given material, reduction and width – the roll load, rolling torque, rolling horsepower and lateral spread of the strip decrease with the diameter of the work rolls. Consequently, for a mill of given roll load capacity and horsepower, greater reductions may be taken with work rolls of smaller diameter. The reduction in lateral spread with reduction in work roll diameter also has considerable practical advantage in rolling the harder metals and alloys since it reduces the tendency of the strip edges to tear or crack. The "stiffness" of the backed-up four-high mill and the ease with which its small work rolls can be crowned have made it possible to produce extremely accurate strip with practically no gage variation across its width. Finally, a smaller work roll permits thinner strip finishing gages even in highly work hardened materials since the length of the flattened arc of contact between the work rolls and material – and, hence, the roll load and rolling torque – decreases with decrease in work roll diameter.

An interesting illustration of the latter phenomenon may be obtained by comparing the roll load and the rolling torque involved in reducing commercially pure Type Ti-75 A titanium strip. The table on the next page compares the load and torque for reducing 6-in. wide strip from 0.015 to 0.012 in. using the 8 x 8-in. two-high configuration and the 2-in. and 8 x 8-in. four-high roll set-up:*

(Continued on p. 164)

*The calculations were made by the method of D. R. Bland and H. Ford (*Proceedings*, Institution of Mechanical Engineers, Vol. 159, 1948, p. 143 to 168), which allows for the effect of roll flattening, based on Hitchcock's formula. The calculations assumed: *(a)* rolling without tensions; *(b)* a constrained mean yield stress of the material being rolled of 1.15 × 84,000 psi. following an intermediate anneal; *(c)* steel rolls with Young's modulus of elasticity of 30,000,000 psi. and Poisson's ratio of 0.3; and *(d)* a coefficient of friction between rolls and strip of 0.10.

Silicon carbide skids replace chrome hearths in seven furnaces, and give . . .

3 Times the hearth life

This forge furnace is one of seven operated by a well-known automotive company. In four of these they heat 16-lb steel slugs to 2250 F, pushing through about 250 slugs every hour. In the others they heat 6-lb billets. All seven furnaces originally had rammed, chrome-ore hearths, but the wear and tear was much too severe. The hearths constantly needed repairs. And in less than three months, they'd be worn out.

Today, all these furnaces have silicon carbide skid rails. These average *nine months' life,* and require few repairs between times. That's only one third as many replacements as formerly required; one third the labor; and one third the downtime.

Figure the total savings! They're sizeable enough to make anyone check for possible applications for our refractories. The easiest way: leaf through "Super Refractories in Heat Treatment Furnaces"—40 easy-to-read pages of picture-caption case histories. Your type of furnace is undoubtedly shown. Write for your copy today. No obligation, of course.

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____

Rolling Mill . . .

(Starts on p. 121)

It is evident that the great reduction in roll load and rolling torque made possible by the four-high arrangement is obtained largely because the small-diameter work roll is much less subject to flattening in the arc of contact. The roll load and rolling torque may be further reduced by employing tungsten carbide work rolls. Cemented tungsten carbides have a modulus of elasticity about twice that of steel and thus tend to reduce roll flattening to the very minimum. The four-high mill with back-up drive is particularly well suited for solid carbide work rolls; the roll shape is simple, the weight relatively small and there is no requirement for torsional loads to be applied through wobblers.

Comparison of Roll Load and Rolling Torque

	Two-High	Four-High
Radius of undeformed work roll	4 in.	1 in.
Radius of deformed work roll	10 in.	1⅛ in.
Roll load	202,000 lb.	49,000 lb.
Rolling torque per roll	65,000 in-lb.	975 in-lb.

Mill Drive – Depending on the range and speed of reduction required, the combination mill may be powered by a constant-speed a-c. motor, a four-speed a-c. motor, a variable-speed a-c. drive with eddy-current clutch or a variable-speed d-c. drive. Similarly, the method of providing front and back strip tension may be varied in accordance with maximum strip pull requirements and coil build-up ratios. In the simplest arrangement on a nonreversing mill, back tension is applied by a friction brake on the pay-off reel, and variable front tension by driving the coiling reel from the main mill motor through an adjustable slipping clutch. A reversing mill may have a variable-speed constant-tension regenerative drive with d-c. equipment on the mill and both reels; dancer rolls control strip tension electronically through variable rheostats or reactors. The greater reduction and flatter strip obtained by applying front and back tension are of particular importance in cold working thin, hard metals; tensions equivalent to one-third to one-half the yield stress of the strip are frequently employed.

The mill motor is generally mounted in the base of the machine and drives the pinion stand through reduction gearing. The mill pinions have double-helical teeth and drive the two large-diameter rolls through silent universal spindles. The lower spindle incorporates a strain-gage torque meter which gives a continuous record of rolling torque. Similarly, a strain-gage load meter is mounted on the axis of each of the top roll-adjusting screws, to give a continuous record of the respective roll loads.

In an all-purpose mill of this type there is much to be gained from driving the back-up rolls rather than the work rolls. Despite the original objection to this method on the ground that slippage would occur between the work rolls and the back-up rolls, extensive and successful service of four-high mills driven by back-up rolls in both the ferrous and nonferrous industries has proved the soundness of this design. The back-up drive eliminates one of the most serious disadvantages of the conventional four-high mill driven by work rolls – namely, the limitation in torque that can be transmitted by

(Continued on p. 166)

Rolling Mill . . .

(Starts on p. 121)

the relatively small roll necks and spindles without exceeding their permissible torsional shear stress. This limitation is particularly serious with carbide rolls, which have a comparatively low torsional strength. Another valuable feature of the back-up drive is its ability to overcome the lateral bowing-out of the small work rolls when heavy reductions with high front tension are taken. Driving the back-up rolls causes a torque reaction on the work rolls which tends to bend them toward the entry side of the mill – that is, in the opposite direction to the force exerted by the coiling reel. By balancing this torque reaction and the strip tensions, the tangential force on the work rolls can be eliminated altogether.

MILL STAND

The housings of the combination two-high and four-high mill are high-strength Meehanite iron castings mounted on a unit base of fabricated steel plate. The housing posts have been designed with large cross-sectional areas to obtain an extremely rigid mill capable of handling severe roll loads without undue deflection. A mechanical roll lift method is employed, using springs in combination with lift rods. The single hand-wheel screwdown is manually operated and is equipped with a simple clutch device for correction of roll parallelism. The opening of the rolls is indicated in thousandths of an inch by micrometer dials directly connected to the screwdown mechanism. Antifriction roll-neck bearings are used on the back-up and work rolls, with ample capacity for both radial loads and end thrust. In the four-high arrangement of the mill, the back-up drive permits the diameter of the work rolls to be changed without changing the rolling speeds.

The standard rolls for the mill are made of close-grained alloy steel, hardened to Rockwell C-64 minimum, and ground and lapped to a mirror finish. When used as a conventional two-high unit, the mill may be equipped also with grooved rolls for round, square and other shapes. Both flat and grooved rolls are available in either chilled iron or a special alloy steel which maintains a hardness of Rockwell C-54 up to 1000° F. For heat dispersion in hot rolling, the mill may be equipped with a self-contained system for circulating, cooling and filtering the bearing lubricant. Certain light gage strip such as molybdenum should be reduced at about 300° F. For such "warm" rolling, heated fluid may be circulated through a central cavity in the rolls, fitted with rotary unions and flexible hose lines.

In rolling heavier gages it is frequently necessary to edge-condition the material. This operation may be combined with the actual reduction in the mill by mounting a vertical edging stand at the entry or exit side. The stand has hardened alloy steel rolls equipped with a number of grooves to match the required edge shape and has a quick-acting roll-opening device operated by cam.

Summary – the desirable features of a versatile laboratory mill may be outlined as follows:

1. Capable of both hot and cold rolling.
2. Capable of handling both flat and shaped work pieces.
3. Readily convertible to either two-high, three-high or four-high roll arrangements.
4. Equipped for accurate measurement of roll loads, rolling torques, screwdown, speed, power consumption and strip tensions.

Beryllium • • •

(Starts on p. 92)

generally at lower pressures, lower temperatures and shorter times than required to bring the compact to density. An alternative method is hydrostatic or pneumostatic hot pressing in vacuo.

Vacuum hot pressing is a basic method for large, fine-grained blocks of beryllium, now capable of producing bodies weighing up to 750 lb. Full density can be achieved when hot pressing at around 1050° C. (1920° F.) at only 75 to 150 psi. with commercial QMV −200-mesh powder. However, 4 to 20 hr. is generally required for a single cycle. Figure 6 illustrates a large unit. Powder is loaded into a steel die as demonstrated in Fig. 7, and the powder mass is sintered under the mechanical pressure of a heavy plunger as shown in Fig. 8.

Direct atmosphere pressing is a method of producing large bodies by pressure and heat without atmospheric protection. It can be carried out at relatively high temperatures, 1000° to 1150° C. (1830 to 2100° F.), if the powder is sufficiently preconsolidated, and if the exposure times are sufficiently short. Temperature and pressure limits are imposed principally by the die materials and lubricants – which may be serious production limitations.

With this method, one is limited by pressure requirements to smaller bodies (weighing 5 to 100 lb.) in equipment such as illustrated in Fig. 9. One advantage is that 5 to 30 min. at pressure is sufficient to reach full density. (The total cycle is considerably greater, depending upon the amount of heating and cooling needed, which, in turn, is limited by the ability to inject raw materials and eject finished pieces at elevated temperatures.) One is restricted to maximum pressures of about 2000 psi. when using graphite dies; maximum temperatures are about 1150° C. (2100° F.) to avoid reaction of beryllium with graphite, especially if the beryllium is unconsolidated powder. Pre-consolidation, even if only by vibration and cold pressing, or by means of cold pressing alone, is of great aid.

Lower temperatures may be used, but they must be compensated by higher pressure, again creating a die problem. In the range from 500 to 1000° C. (930 to 1830° F.) high-nickel and cobalt alloys or certain sintered carbides have been used experimentally, but they are costly and relatively unreliable. Graphite may be protected at higher temperatures by iron, nickel, or molybdenum sheaths as well as by glass or ceramic liners and mold washes. However, properly consolidated beryllium, handled carefully, can be hot pressed without the aid of these auxiliary materials, although the rate of die wear may become excessive, whereupon the carbide attack on beryllium is faster from the roughened and eroded die walls.

DENSIFICATION TO SHAPE

Warm pressing involves compacting somewhat below the recrystallization range (about 300 to 650° C.) but chiefly between 400 and 500° C.

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Beryllium . . .

(Starts on p. 92)

(750 to 930° F.). Pressures range from 50,000 to 200,000 psi. Hot work toolsteel dies can be used and rapid pressing or coining cycles are possible.

Direct hot pressing, when using hard graphite or special die materials, will produce small parts weighing a fraction of a pound rapidly. Success generally depends upon the die life.

Coining – Semiconsolidated parts – cold pressed and sintered, warm pressed, or hot pressed – can be brought to satisfactory density when coined at 400 to 600° C. (750 to 1110° F.). If this operation is rapid, little surface oxidation takes place, especially when the temperature is on the low side.

Forging – Beryllium powder can be pressed to shape in contoured steel cans. The can is heated in an inert atmosphere to 1000 to 1150° C. (1830 to 2100° F.), placed in a die heated to 400 to 800° C. (750 to 1470° F.) and compacted at 2000 to 10,000 psi. Relatively sharp contours and closely dimensioned pieces have been made rapidly (in 4 to 7 min.) in parts weighing up to 15 lb.

PRODUCTION OF SEMIFINISHED BODIES

Semifinished bodies or billets for extrusion, rolling, forging, or tube drawing can be made by any of the methods described. Generally, densities from 70 to 90% of theoretical are desired depending upon the degree of noneffective deformation which one can tolerate in the hot or warm working to which the subdensity billet will later be subjected.

Hydrostatic Hot Pressing – The vacuum envelope pressing technique was developed for intricate, dense bodies. It uses very low pressure at high temperature. It is based on hydrostatic or pneumostatic pressing of powder at 1000 to 1100° C. (1830 to 2010° F.). The beryllium powder is encased in a thin-walled steel form whose internal surface is shaped to the desired contours, which is then placed inside a heated pressure vessel. The intervening space is filled with a nonsintering, permeable ceramic, such as silicon carbide.

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Beryllium . . .

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This intervening space is then pressurized with argon to 100 to 300 psi. The steel can or form containing the beryllium powder is then connected with a vacuum pump and evacuated to 50 microns.

In effect, one is reproducing the same conditions wherein large blocks are made by vacuum hot pressing at low pressures; however, shapes of intricate surface and long length in relation to diameter are produced. An assembly for making six rods of triangular cross section is shown in Fig. 10. The process is well adapted for long (7-ft.) finned tubes or rods with irregular cross sections. Satisfactory surfaces can usually be had by grinding or machining.

PRODUCTS AND PROPERTIES

The usual commercial product is now a large block, vacuum hot pressed, shown in Fig. 11. The photograph was taken after pressing and chemical cleaning. This slab is next milled to remove low-density metal along the edges. The trimmings are then recycled through the comminution process, and if properly handled, they pick up no impurities other than 0.1 to 0.2% BeO. Machined slabs pressed in the horizontal vacuum hot pressing unit shown in Fig. 6 have been made in sizes up to 51 x 24 x 4 in.

Direct pressing can also result in a wide range of formed products, usually small because of the large pressures necessary. Compacts forged at high temperature can form rough cakes which can generally be machined to size. Bodies formed at high pressure and low temperatures are to closer dimensions, but the lower the temperature, the higher the pressure needed. Higher pressures mean smoother surfaces, but pressure limitations generally result in smaller bodies.

For subsequent hot deformation it is usually advisable to start with material which is slightly below density, such bodies having lesser strength and greater deformability than the full density pressings.

Alloys — Using the methods described above, similar compacts can be made from a wide variety of beryllium alloys and cermets by mixing the powdered, pre-alloyed or reacted material with the beryllium powder before hot pressing. Alloys can also be formed during the hot pressing operation by mixing beryllium directly with the metal to be alloyed. One usually makes a subdensity material by vacuum hot pressing, and then atmospheric hot pressing the compact at relatively high pressures, to overcome distortion in the metal matrix usually caused by formation of compounds.

If the alloying element has a lower melting point than the pressing temperature for beryllium, the mixture must be pre-pressed before hot pressing. Canning is desirable to protect the dies. If the materials are highly susceptible to oxidation, the mixing and the pre-pressing are done under dry, inert atmospheres in a dry box.

Bimetallic bodies may be made by pressing beryllium powder around a solid piece of the material to be clad, either directly or hydrostatically, or by pressing a core of beryllium

powder into a sheath, and then rolling to the desired shape.

Properties – Tensile properties of fabricated beryllium powder are reviewed in Fig. 1. Mechanical work may be required to bring out the optimum properties.

Tensile elongations are usually from 2 to 5% for vacuum hot pressed QMV at room temperature; test results vary with the rate of application of load. Higher elongations than 5% are found occasionally in experimental techniques. The ultimate strength of vacuum hot pressed metal varies from 40,000 to 50,000 psi. with yield strength of 30,000 to 35,000 psi.

The most valuable characteristic of vacuum hot pressed beryllium is that the properties (unlike all mechanically worked metal which is strongly directional) are quite isotropic and independent of the direction of testing. Presumably, this is a function of the rather low pressures used, and the random orientation of the original powder particles.

SUMMARY AND TRENDS

A wide range of mechanical and chemical properties may be developed in beryllium through fabrication by powder metallurgy, depending upon the type of powder and the method of fabrication. Mechanical properties are mainly controlled by the grain size (which, in turn, is determined by the particle size of the powder), the amount and distribution of BeO and other impurities, and the degree of consolidation. Optimum room-temperature properties generally require fine grain size, maximum consolidation, freedom from impurities – particularly those forming compounds with beryllium. Above 500° C. (930° F.), a coarser grain size as well as the prevalence of more refractory compounds apparently increases the strength. For fabrication by mechanical work, however, relatively weak metal with as much ductility as possible is desired.

Economics in processing is largely a function of avoiding loss or devaluation of the expensive raw material. Consequently, one must fabricate as near to final dimensions as possible or handle scrap in a manner whereby it can be recycled with little or no loss in value. Other than this, the primary economic factor (generally typical for powder metallurgy) is to have sufficient operating volume to justify the production of any one particular item.

Trends – Processing of beryllium through powder metallurgy, which at present is the only commercial fabrication method, will probably trend away from the job-shop type of operation (involving the vacuum hot pressing of powder into large blocks followed by machining) into direct processing to shape on an automatic basis. This will occur if parts can be standardized and sufficient volume is developed.

Two technical problems still remain to be solved to insure smooth and efficient operation. One is to find stable lubricants for high temperatures which will not damage the beryllium or the processing die either by erosion or reaction. The other problem is to devise new materials for dies and containers which can withstand the relatively high pressures and temperatures needed to process beryllium and develop its optimum properties.

Influence of pH on the Corrosion of Metals*

THE WORK of Akimov and Rozenfeld, according to the author, stands out because in the vast literature on irreversible potentials, only it systematically considered the influence of the concentration of hydrogen ions – the most essential factor in corrosion behavior. In the present work a further study was made of

(Continued on p. 176)

*Digest of "Influence of pH on the Electrochemical Behavior of Metals and Their Corrosion Resistance", by A. Ya. Shatalov, *Doklady Akademii Nauk SSSR*, Vol. 86, 1952, p. 775-777.

Fig. 1 – Region of Irreversible Electrode Potentials of Molybdenum, Tungsten, Silver and Bismuth, and Curves of Corrosion Rate. Open circles indicate electrode potentials; curves 1 and 2 refer to 1.0 N and 0.001 N chloride-ion solutions, respectively. Curves 3 refer to weight losses due to corrosion.

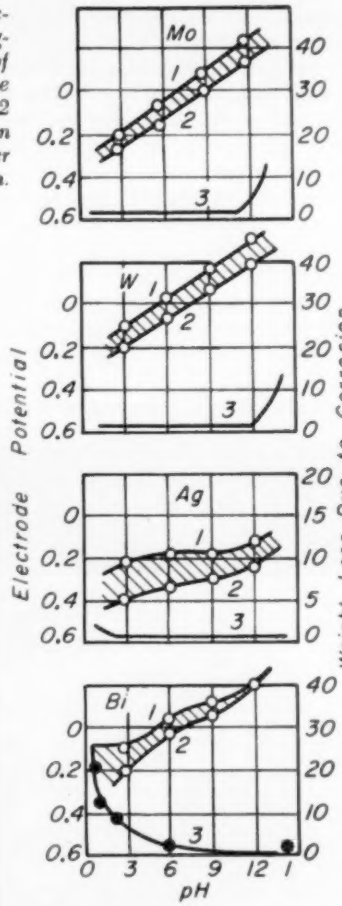
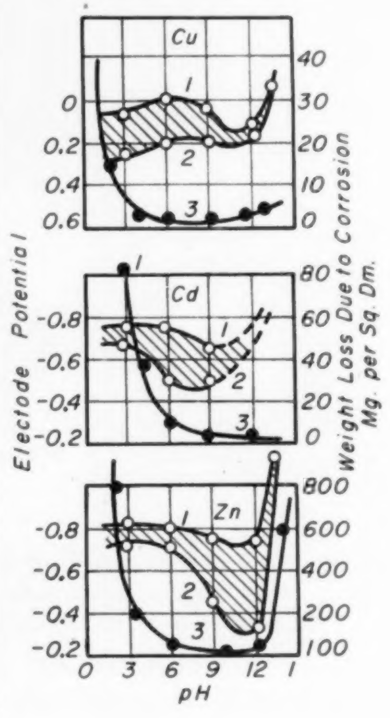


Fig. 2 – (Below) Curves for Copper, Cadmium and Zinc



Corrosion . . .

(Continued from p. 174)

this matter, taking into account the role of corrosion-active foreign ions, especially chloride ions. Measurements of electrode potentials were made for the 12 metals, silver, copper, magnesium, zinc, cadmium, aluminum, lead, tin, bismuth, molybdenum, tungsten and manganese in solutions with various pH and with chloride-ion concentrations of 0.001, 0.01, 0.1 and 1.0 *N* (normal). Buffered and unbuffered solutions were used to span an interval of 10 units of pH. Direct weight or volume methods of corrosion testing were employed.

Results of the electrochemical measurements and of the determinations of corrosion losses are given in Fig. 1 through Fig. 4.

Although each metal has its characteristic region of irreversible potentials (shown as a shaded region in the figures), it is possible to distinguish five types of these regions:

1. The simplest type occurs as a narrow band, as for molybdenum, tungsten, silver, and bismuth, Fig. 1

2. Copper has a more complex region, which is produced by the simultaneous action of several factors that determine the potential, Fig. 2.

3. The regions characteristic of cadmium and zinc belong to a third type, shown in Fig. 2.

4. Lead, tin, and aluminum belong to a fourth type, Fig. 3. Regions of types 3 and 4 are influenced by the amphoteric nature of the hydroxides of these metals.

5. Magnesium and manganese form the last type of region of irreversible potentials; one that is only slightly influenced by changes in pH or chloride-ion concentration. This type is shown in Fig. 4.

It is not possible to establish any simple relationship between the behavior of the electrode potentials of metals and their corrosion resistance.

(Continued on p. 178)

Fig. 3 – Electrode Potentials and Corrosion Curves for Lead, Tin and Aluminum

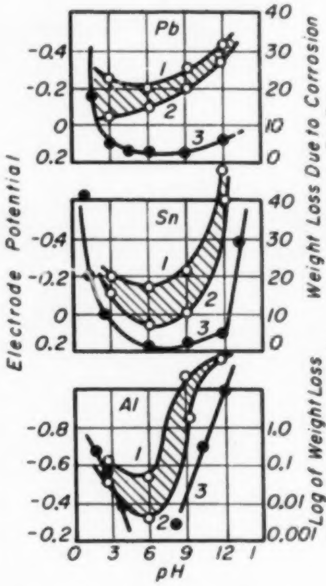
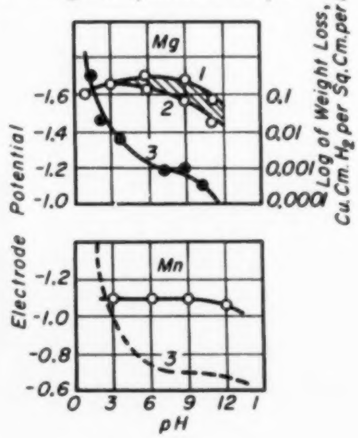


Fig. 4 – Curves for Magnesium and Manganese. The corrosion curve for manganese is an approximate one obtained by measuring the current of a manganese-platinum couple



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Corrosion . . .

(Continued from p. 176)

On the basis of rate of corrosion, these twelve metals can be classified into five groups: *(a)* molybdenum and tungsten; *(b)* silver and bismuth; *(c)* cadmium; *(d)* copper, zinc, aluminum, lead and tin; *(e)* magnesium and manganese. The curves of corrosion resistance generally did not show a pronounced change in form with change in chloride-ion concentration. For aluminum, however, the region of good corrosion resistance between the two branches of the K-pH curve became increasingly narrow as the concentration of chloride ion increased. A. G. Guy

Detecting Troubles*

As engineers we go through the following steps before we have assurance that the process of manufacture is satisfactory:

1. Determine the quality that is wanted through consumer research.
2. Perform research and development work to devise means for fulfilling these consumer wants at a reasonable cost.
3. Design and specify the product selected and in so doing set tolerance limits.
4. Make the product specified.
5. Inspect the product for conformance to design and specification.
6. Test the product in service (operational research) to see that it satisfies the wants of the user in an adequate, dependable and economic manner.

To the extent that we as engineers have been able to associate physical data with assignable causes, these causes may be classified by the types of physical data that they produce, namely:

1. Gross error or blunder (shift in the individual).
2. Shift in average or level.
3. Shift in spread or variability.
4. Gradual change in average or level (trend).
5. A regular pattern of change in level (cycle).

(Continued on p. 180)

*Digest of "How to Detect the Type of an Assignable Cause", by Paul S. Olmstead, *Industrial Quality Control*, Vol. 9, November 1952, pp. 32-36, and *Bell Telephone System*, Monograph 2106, September 1953.

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Detecting Troubles . . .

(*Continued from p. 178*)

To detect an assignable cause there are five general classifications of statistical tests – control charts, extreme differences, runs, nonparametric association, and analysis of variance. At least two subgroups exist for each. In all, 17 ways of measuring the evidence for the various types of trouble are indicated. The following five methods, however, can usually be relied upon for identification:

1. $P\lambda$ for gross error.
2. Runs in x above and below for shift in average.
3. Runs in R above and below for shift in variability.
4. Runs in $\bar{x}$ up and down for a trend.
5. Runs in x up and down for a cycle.

Having derived a systematic procedure for detecting trouble, it is now necessary to consider when, where, and how it should be used. What situations are commonly encountered by the engineer and what measures should be used in these situations as a basis for looking for trouble? There are but two classes of situations, one of these being associated with manufacture and production, the other with research and development.

It is important that control procedures to be adopted in production do not interfere in any important way with the actual process of turning out units of product, unless the indicated deviation in product quality is "economically" worth finding. In the case of research or development, the objective is not the same as in production. The engineer is not satisfied in carrying out his researches unless he can identify and measure the effect of each factor that must be controlled to produce minimum variation in the measure that he is making. For this reason, he looks for the patterns in his data that he has associated with particular types of variation in the past. It is for his work that the procedures outlined here have been found useful. Sometimes the information may be so sketchy that he does not know or he may not realize that he has a basis for knowing what type of assignable cause to look for. It is part

(*Continued on p. 182*)

Big step in making washdays easier

Quality of modern detergents is accurately controlled with G-E x-ray diffraction units

THE girl's hands in the above photograph are loading a sample holder in the laboratory of a detergent manufacturer. Every day carload shipments of these washday products must be checked to insure housewives of unvarying quality.

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Many other industries now look to x-ray diffraction for both research and production control. On such widely diverse products as antibiotics and ceramics, paper and titanium, plastic and petroleum — this flexible, yet highly accurate, non-destructive technique is used.

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Detecting Troubles . . .

(Continued from p. 180)

of the job of the engineering statistician to help the engineer resolve this dilemma.

Based on his research and development studies, it is possible for the engineer to select average values for each of the characteristics that are to be measured for the product. It is these values that represent the intent of design. They are values established from his development studies as being the ones necessary to give a satisfactory product. As the design goes into production, some of the values desired by the engineer are likely not to be met. At this stage, production research takes over to establish the average values that will apply as quality levels to be maintained by the process that has been established. These levels may or may not be identical with those set by the development engineer. If, as frequently happens, they are not, he must agree to them as being sufficiently close to what he selected and as being satisfactory for the kind of product he intended.

Capability with respect to product variability is the special field of production research. It is established for each of the measured characteristics during the period while production is being started. It is most important at the beginning to use methods of the type discussed here to locate and identify as soon as possible the various assignable causes that have to be considered for the product.

If this preliminary examination is properly carried out then when full production is established, greater reliance may be placed on the control charts for averages and ranges alone. It is during initial production that the major causes of trouble are determined and steps taken to see that they are brought under control.

To be on the safe side, it is usually preferred to use samples of the order of 1000 to establish tolerance limits, particularly if they are to be taken as specification limits to be met in production and inspection. In order to make such limits effective, it is necessary in production to use control limits on the averages and ranges of consecutive samples as a basis for corrective action to see that the process remains in statistical control.

(Continued on p. 184)

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Detecting Troubles . . .

(Continued from p. 182)

The processes of analysis that have been described are designed to uncover in an orderly fashion evidence for the presence of assignable causes that might elude the engineer or scientist. If such a cause had been suspected, provision might have been made in the experiment to measure its effect. Discussion with the engineering statistician often suggests such causes that might ordinarily be overlooked. Hence, it is helpful for the engineer and statistician to work together as a team to plan the experiment. The engineer supplies the technical knowledge in the applied field and the statistician, knowledge of variability and of how to detect and identify evidence that may be associated with assignable causes.

MYRON WEISS

Industrial Uses of Microradiography*

MICRORADIOGRAPHY is the radiographing of a thin sheet of material, on a photographic emulsion of sufficiently fine grains so that a subsequent enlargement may be made. The method depends on the differences in absorption of X-rays by the various constituents of the sample. It supplements microscopic inspection by recording the volume characteristics of the material to permit the recognition of phases and inhomogeneities; however, it is not capable of the magnification obtained with the microscope.

Much work has been done using microradiography for studies of spot welds, segregates, iron ores and sinters, phase changes, chemical composition (qualitative), stresses and crystal distortion. The method has been extended to materials such as fibers and fabrics, colloids, minerals, plant tissues and fossils. This paper is a report of the application of microradiography to several fields.

The method of preparing microradiographic samples of nonferrous metals is to obtain a specimen not

(Continued on p. 186)

*Digest of "Some Industrial Applications of Microradiography", by S. Goldspiel and F. Bernstein, *Nondestructive Testing*, Vol. 11 May 1953, p. 15-20.

Microradiography . . .

(Continued from p. 184)

more than 0.005 in. thick, ± 0.0003 in., with surfaces as nearly parallel as possible. The method is described in detail. The limitations on the thickness are imposed by the intensity of the X-ray diffraction tube, the absorption of the component elements, and the magnitude of repetitive structural units, as well as the speed and graininess of the photographic emulsion. The tolerance in thickness is estimated from differences which would cause density variations of the order of magnitude resulting from composition differences of the material.

Four photomicrographs with their corresponding microradiographs of a copper-base alloy (gun metal) are presented. The microradiographs supplement the photomicrographs because porosity is indicated for a volume rather than for a single surface and the contrast between various phases is clearer.

In addition, photomicrographs and microradiographs of plastic-coated sound projection screen cloth, polyester glass laminate, aluminum-glass laminated cable sheathing, fiber battery separator, silicone glass laminate, welding electrode coating, and cracked rubber impregnated with lead salt, are included. The technique offers several advantages.

Their technique eliminates the need for using chemicals to remove opaque coatings, reveals constructional features, and provides a permanent and an easily stored record. It permits studies of the causes of failure, comparisons of chemical penetrations with life expectancy, and observations on homogeneity. Details of type of radiation, film distance and exposure, and developing methods are included for the thread count experiments.

The study of cracks in a rubber surface is interesting. The cracks were filled with a lead salt and a microradiograph taken. A series of microphotometer traces were taken along representative line elements of the radiograph. The percentage of cracked surface is calculated from the combined width of the trace pips, the known area of the microphotometer slit and the known recorder magnification.

(Continued on p. 190)

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The new Center is dedicated to just one end: to help you develop and produce ever better, ever more versatile metals through helping you find new, practical solutions to your most difficult technical problems.

To achieve that end, we have made the new Center what we believe to be one of the finest of its type anywhere in the metals industry.

We have made it a living symbol of the traditions, the achievements, the ultimate goals shared by Vanadium Corporation and the metals industry as a whole — as well as a new means to future service and prosperity for both.

We cordially invite you to visit our new Research Center next time you are in the vicinity.

W. C. Keeley
President

Vanadium Corporation of America

Microradiography . . .

(Contnued from p. 186)

Although most of the work was done using the usual method of photographic record, direct reading methods may be applied. This kind of determination was made of the thickness and uniformity of 0.0002-in. coatings of gold, silver, and nickel on quartz oscillator crystals. The work was done using a Geiger-counter X-ray spectrometer.

The authors plan to make experiments which will expand the basic usefulness of the method by the introduction of direct reading methods. The plan calls for the development of a sharp, finely collimated X-ray source which could be scanned over a standard area of a wafer of metal to provide transmission data for correlation with a factor combining soundness, homogeneity, and grain structures of materials.

Elizabeth Hartner

The Low-Shaft Furnace*

Before constructing a low-shaft furnace an attempt has been made to estimate the advantages and disadvantages. Because of its great height the conventional blast furnace demands the use of metallurgical coke even though it is used with excellent thermal efficiency. Good, strong coke, however, is becoming scarce on the European continent, and the cost per calorie is 30 to 40% more from coke than from coal.

A low furnace does not need such strong coke, but to shorten the furnace, while maintaining the same top gas temperature, it is necessary to reduce the average particle size of the burden or else to use oxygen-enriched blast.

A decreased furnace height brings other disadvantages: The throughput time becomes much shorter and this might cause a greater amount of direct reduction of the ore to iron. This would clearly be less serious than in the blast furnace since a poorer quality of fuel may be employed. It may even become an ad-

(Continued on p. 192)

*Digest of "Exposé Général Sur le Bas Fourneau", by H. Malcor, *Revue Universelle des Mines*, August 1953, p. 470. Mr. Malcor is president of the international research committee on a low furnace for reducing iron ore to pig iron.

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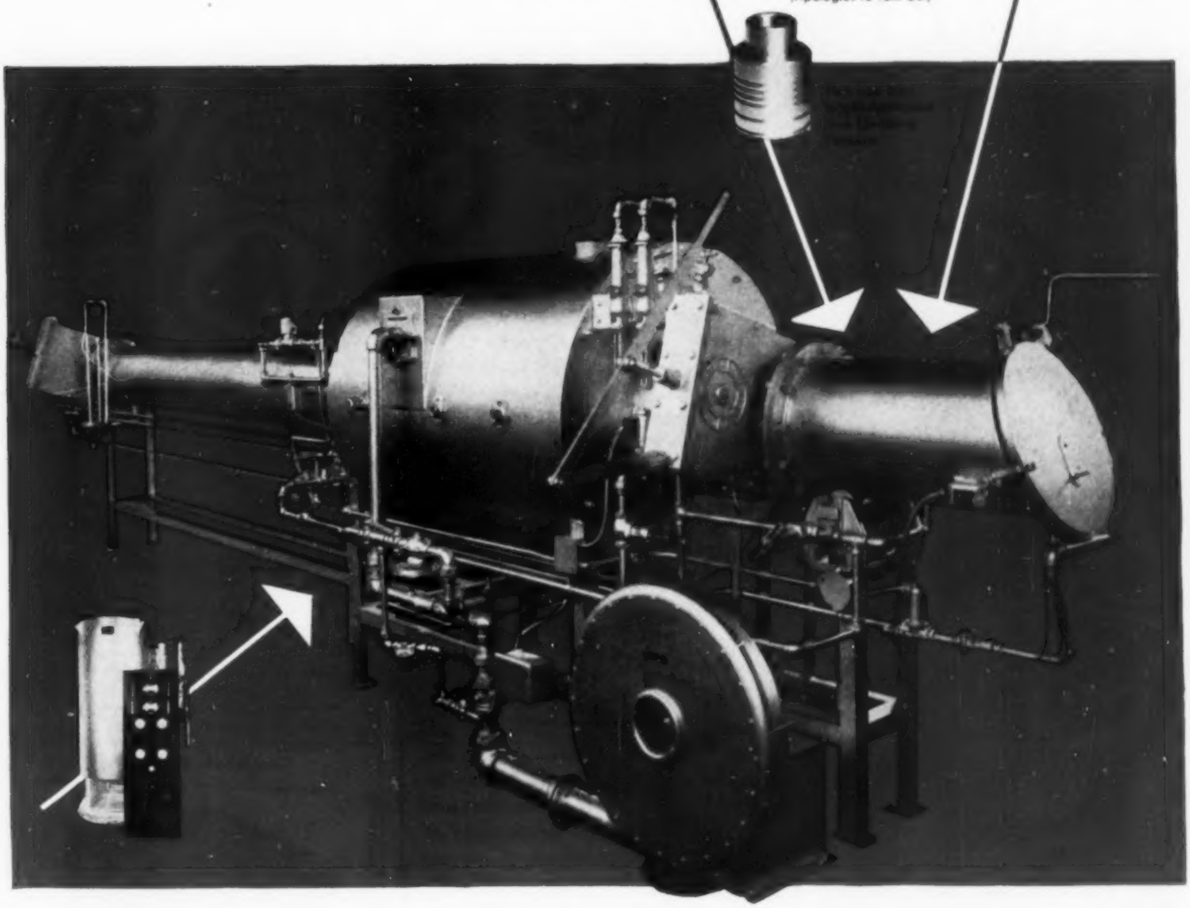

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Low-Shaft Furnace . . .

(Continued from p. 190)

vantage if the fuel calorie costs less than the gas calorie which it could otherwise produce at the furnace top. If the charge is inadequately prepared there is the added danger of insufficiently reduced material descending into the hearth; if such is refined in the hearth it would involve "slag working", producing iron high in both sulphur and silicon.

There are, however, means of reducing if not avoiding these phenomena as encountered in the blast furnace. The first is to provide a narrow hearth – that is, preventing the existence, at the axis, of a mass of material which though hot is not reached directly by the tuyere combustion zone. Thus, the furnace is elongated in plan to the rectangular shape of a modern blast furnace for smelting copper sulphide ores. Such an arrangement presents further difficulties in complicating the construction, suffering a higher radiation loss, uneven descent of burden, more complicated charging mechanism, and risk of segregation and difficulties in the corners of the shaft.

A second method of avoiding "slag working" is based on a decrease in particle size. It is proposed to begin with dimensions of 10 to 40 mm. Another question which may arise is whether direct reduction will have time to take place during the short period allotted to it. It may be thought that, at the temperatures existing, the reactions are so rapid as to be quasi-instantaneous. However, this is not absolutely certain. Conditions may be favored by improved contact between ore and reducing agent – that is, by briquetting – or by pulverizing the charge to produce a very small grain size.

Thirdly, a "hot" iron may also be produced, insuring that safe working is maintained with the hearth able to digest any slips or falls which may occur – but the aim is to make a basic bessemer iron, that is to say, a cold iron.

There are some disadvantages in operating a low shaft furnace with enriched blast. If the oxygen is increased, thereby lessening the amount of nitrogen ballast, the gas leaving the hearth, for example at 2200° F. (1200° C.) may no longer

(Continuer on p. 194)

Low-Shaft Furnace . . .

(Continued from p. 192)

contain sufficient calories to complete all the processes necessary to bring the charge to the desired state at the focus, such as dehydration, removal of water of crystallization and breaking down carbonates, and physical heating pure and simple. This danger is doubtless only present if the oxygen in the blast exceeds 40 to 45%.

This may also become an advantage in other circumstances. A problem much studied at present is that of ore concentration. For Lorraine ore this entails grinding below 0.5 mm. with previous drying. The concentration processes – especially magnetic roasting – would be especially interesting if they could simultaneously completely dehydrate and calcine the mixture.

Returning now to the low shaft furnace constructed at Liège, the following details are given: (*a*) The furnace is oval in shape; (*b*) two charging systems may be used – either alternate layers or mixed burden; (*c*) ore briquetting is not contemplated.

Experience will show whether the iron produced must be desiliconized after leaving the furnace or if, on the contrary, it will be necessary to briquette the charge to obtain a less siliceous iron. Briquetting, of course, has many disadvantages.

Some other considerations are given as follows:

The low shaft furnace has a thermal and material capacity much smaller than that of the conventional blast furnace, and cannot therefore act as a self-regulator. A burden of smaller particle size is expected to mitigate this danger. In addition, oxygen in the blast provides a new means of regulation.

A *priori* it might be thought that oxygen should be avoided since it is more expensive than the oxygen naturally in the air. However, if the furnace can be made to run on lower pressure, and since less energy is needed to pump a smaller volume of gas, a notable part of the extra cost due to oxygen may be recovered.

The preparation of the burden presents a further additional expense but not without a counterpoise. The question of fine ore is of great importance, as more and more ore fines

(Continued on p. 196)

Low-Shaft Furnace . . .

(Continued from p. 194)

are produced, and this in itself is a factor favoring the use of the low-shaft furnace. However, the fines produced by Lorraine ores are extremely small, mostly below 1 mm. Conditions change radically when charging ore of 10 to 20-mm. size, as is going to be done at first in our examination, and when one must charge ore below 1 mm. in average particle size. Very fine ore brings certain attendant disadvantages: It tends to work well at first but then forms lumps impermeable to gas or else filters through the charge and descends much too quickly into the hearth. It is possible that, if the low-shaft furnace using oxygen cannot deal very conveniently with fines, a solution may be found when operating with high top pressure.

The combustion zone would be lower in the low-shaft furnace, and this way permit slag compositions which are normally either too fluid or too refractory.

The combustion zone in the low-shaft furnace using oxygen is also at a much higher temperature, and it produces a richer gas.

Ultra-Pure Metal

THE ELECTRICAL and electronics industries have become interested in certain metals of exceptional purity, or such pure metals plus carefully limited amounts of certain "impurities" because of their good electrical or magnetic characteristics. For example, commercial Armco iron, purified to 99.987 by hydrogen and vacuum annealing, has maximum permeability of 30,000; if further purified by a long, high-temperature heating cycle to 99.989 the figure jumps to 227,000.

Germanium is another instance*. The metal has great importance as a

(Continued on p. 198)

*See abstract of "Metallurgy Behind the Decimal Point", by Earle E. Schumacher, *Metal Progress*, February 1951, p. 280; "The Metal Germanium and Its Use in the Electronics Industry", by Anthony S. Rugare, *Metal Progress*, August 1952, p. 97, and "Ultra-Pure Metals Produced by Zone-Melting Technique", by Earle E. Schumacher, *Journal of Metals*, November 1953, p. 1428.

Ultra-Pure Metal . . .

(Continued from p. 196)

transistor or solid rectifier of alternating current. Certain elements (As, Sb, P, Bi) are necessary "impurities"; nevertheless 0.001% arsenic – one atom of arsenic to every 100,000 atoms of germanium – is ruinous.

Ultra-pure germanium would obviously be a desirable material for electronic manufacture and physical research. "Quality" factors of common metals also are frequently so ill-defined that sceptics look upon them as prejudices or imaginary. Nevertheless, as Earle Schumacher, chief metallurgist of Bell Telephone Laboratories, points out in the last citation in the footnote: "Copper from Chuquicamata, Chile, has in it something or other making it uniquely adaptable to certain copper oxide rectifier applications. Copper from nowhere else in the world can be used for these purposes. The quantity of *mystery stuff* involved is so small as to defy positive detection by all available analytical tools – including the mass spectrograph."

Ultra-pure copper might be a starting point for a metallurgical detective looking into this mystery.

"A new method for purification has been developed in the metallurgical department at Bell Telephone Laboratories, known as zone-melting. The method was first applied to germanium with fantastic results. The impurities critical to the behavior of germanium as a semiconductor, such as phosphorus, arsenic, and antimony, are being reduced to a concentration as low as 1 atom per 10 billion atoms of germanium."

The method is simple. A long bar is contained in a snug boat and passed through a quartz tube around which are placed at equal intervals a half-dozen induction coils. As the solid bar enters the zone of each coil, a short length of it melts. Each melted zone progresses from end to end of the bar as the boat is pushed slowly along. The moving liquid picks up and carries along a greater proportion of the impurities, leaving purer solid behind. Each successive zone causes further refining. Most of the impurities are concentrated in the last volume to freeze. This impure section may then be cut off.

(Continued on p. 200)

Ultra-Pure Metal . . .

(Continued from p. 198)

"Impurities which raise the melting point can be removed by zone-melting also, although the mechanism is somewhat more complicated. In this case impurities travel in a direction opposite to that of the zone and, in general, more passes are needed." E. E. T.

Properties of Sintered Nickel Steels*

By using high pressures, double pressing and hot pressing procedures, it is possible to produce sintered steels of high density; mechanical properties can be improved with the addition of alloying metals. However, considerable care must be exercised in selecting the additive alloys so that the constituents are in equilibrium with each other at usual sintering temperatures. It has been shown by L. Delisle and A. Finger, and by L. Delisle and W. V. Knopp (American Institute of Mining and Metallurgical Engineers, Technical Publications No. 2046, and No. 2340, for 1946 and 1948 respectively) that high sintering temperatures and long sintering periods are required for nickel-iron alloys containing from 0 to 100% Ni and

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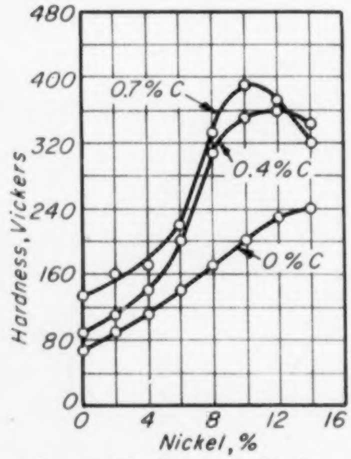

Fig. 1–Hardness of Single-Pressed Sintered Nickel Steels

*Digest of "Sintered Nickel Steels," by F. Benesovsky, *Berg und Hüttenmannische Monatshefte*, Vol. 96, September 1951, p. 184-187.

Sintered Steels . . .

(Continued from p. 200)

for nickel steels containing up to 10% Ni.

The author prepared test samples of sintered steels having from 2 to 14% Ni and 0 to 0.7% C by the following procedure: Powdered iron (of Armco-iron purity and having a grain size of about 0.015 mm. for 50% of the grains, 0.06 mm. for the rest) was mixed with 2, 4, 6, 8, 10, 12 and 14% powdered nickel carbonyl, while another group was mixed with 0.4 and 0.7% of very finely powdered graphite. Flat specimens for tensile testing were pressed from these mixtures, the pressure being about 85,000 psi. The rods made of carbon were sintered for 4 hr. at 2230°F. in sealed graphite containers in a sintering furnace using a dry hydrogen atmosphere. The iron-nickel alloys that contained no graphite were sintered for 4 hr. at 2340°F. in iron containers. The specimens which were to receive double pressing were given a preliminary sintering at 1650°F. for ½ hr. This was followed by compacting at a pressure of 114,000 psi., and finally by sintering at 1650°F. The resulting properties of the nickel steels made by single and double pressing procedures are given in the accompanying tabulation and in Fig. 1 and Fig. 2.

Hardness of the carbon-free sintered steels increased almost proportionally with increasing nickel contents. Maximum hardness appar-

(Continued on p. 204)

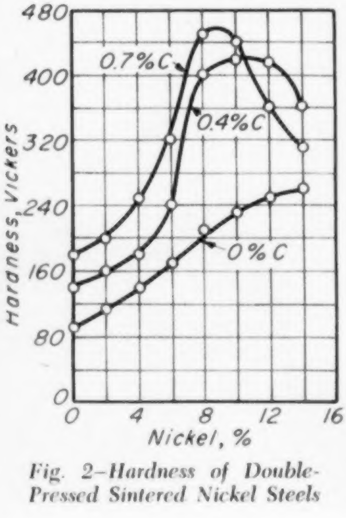

Fig. 2—Hardness of Double-Pressed Sintered Nickel Steels

Sintered Steels . . .

(*Continued from p. 202*)

ently was not reached even in specimens containing 14% nickel, this being the composition in which formation of martensite began. In the sintered steels which contained 0.4 and 0.7% carbon, marked maximum values can be observed in the hardness; also, the maximum hardness value shifted toward lower nickel concentrations with increasing carbon (this being in accordance with L. Guillet's observations carried out with molten nickel steels.

In the samples made both by single and double pressing procedures, maximum hardnesses correspond to 10 to 12% Ni for specimens containing 0.8% C. With the occurrence of austenite, hardness decreases as the nickel concentration increases. In judging the hardness values, however, it should be taken into account that these only permit conclusions concerning the surface structure of the specimen. Regions of lower hardness and strength can occur inside the specimen, these being caused by cooling conditions prevailing in the sintering furnace.

Maximum values, as observed when hardness is plotted against nickel or carbon content, are also found in the tensile strength of double-pressed nickel steels containing 0.4% C and 10% Ni, whereas, on the basis of hardness values, steels containing 0.7% C should have maximum tensile strength at 8 to 10% Ni.

OTTO MIRT

Properties of Sintered Nickel Steels as Related to Method of Compacting

% Ni	0% C†		0.4% C‡		0.7% C§	
	Tensile 1000 Psi.	Elong., %	Tensile 1000 Psi.	Elong., %	Tensile 1000 Psi.	Elong., %
2(a)	84.0	26	102.2	12	114.3	8
2(b)	92.6	32	131.5	16	135.0	2
4(a)	89.8	24	127.1	10	123.9	6
4(b)	100.0	28	140.7	12	142.8	2
6(a)	108.0	18	152.5	8	131.3	0
6(b)	119.6	24	154.0	8	155.1	1
8(a)	126.2	16	172.7	4	136.8	0
8(b)	143.8	16	182.4	2	172.7	1
10(a)	154.5	12	184.8	2	113.8	4
10(b)	163.2	12	206.1	1	128.1	4
12(a)	173.8	12	176.9	6	97.4	6
12(b)	191.9	12	198.8	4	102.1	8
14(a)	184.0	10	166.6	8	83.2	8
14(b)	206.0	10	166.2	8	82.8	12

(a) Samples made by single pressing at 85,000 psi.

(b) Pressed at 85,000 psi. and compacted at 114,000 psi.

†Sintered pieces, made so as to be practically free of carbon.

‡Sintered pieces with 0.28 to 0.48% carbon added as graphite.

§Sintered pieces with 0.64 to 077% carbon added as graphite.

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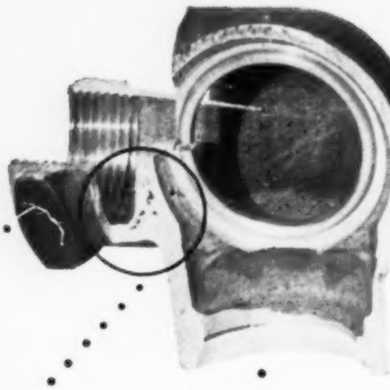

Shrinkage

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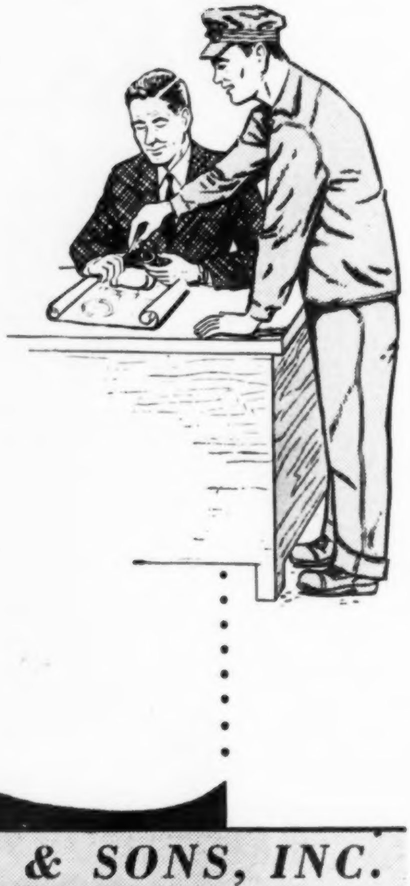

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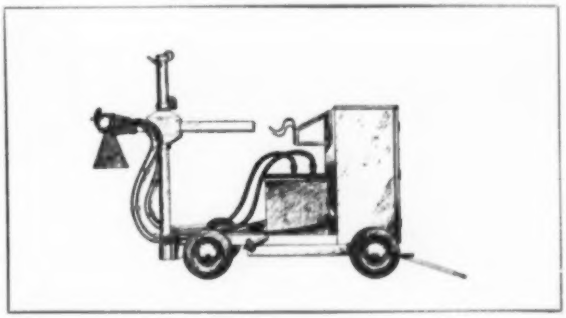

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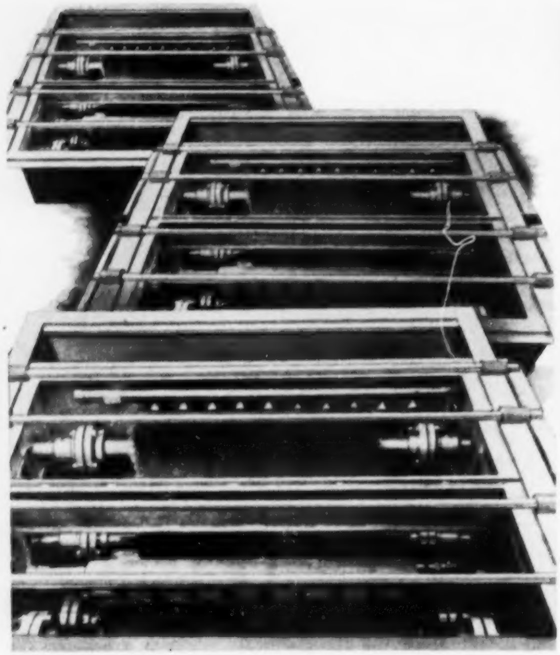

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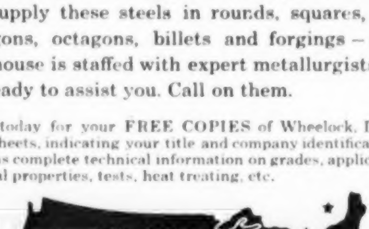

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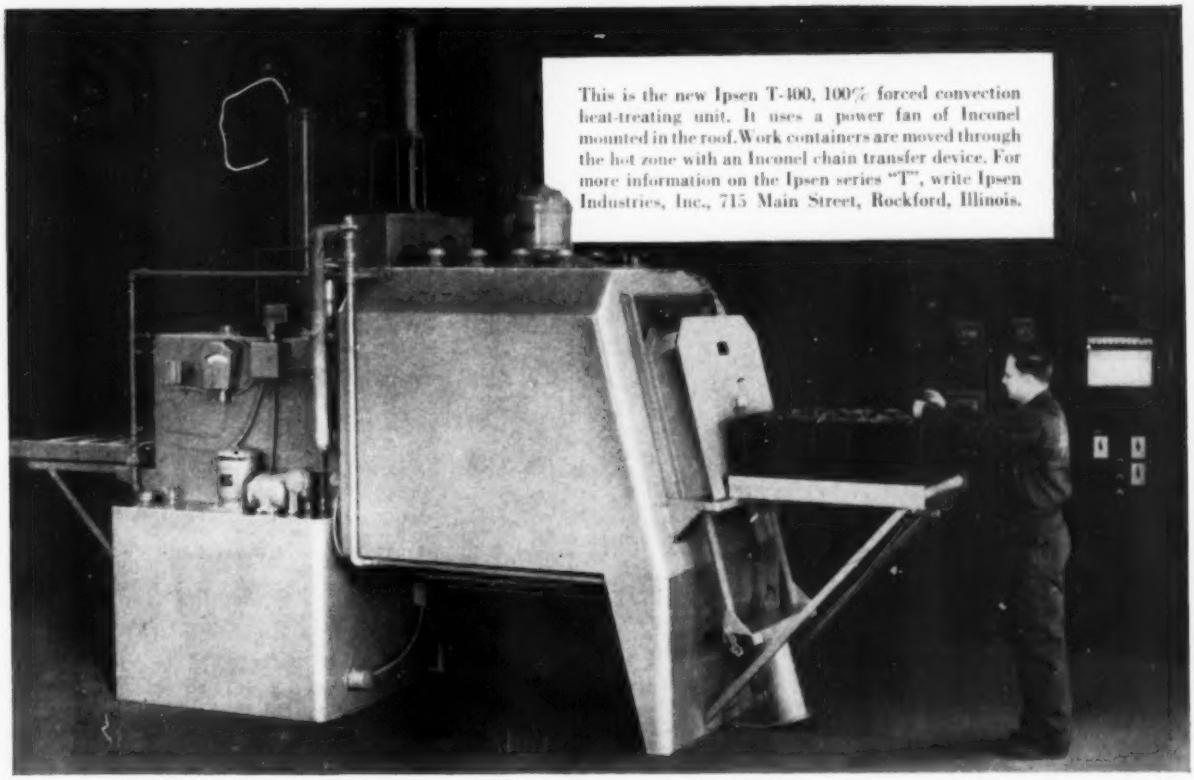

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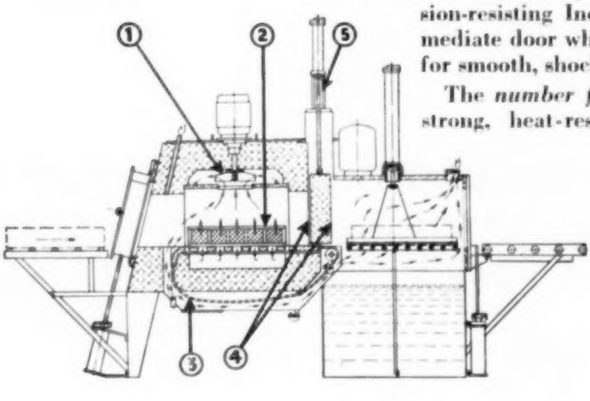

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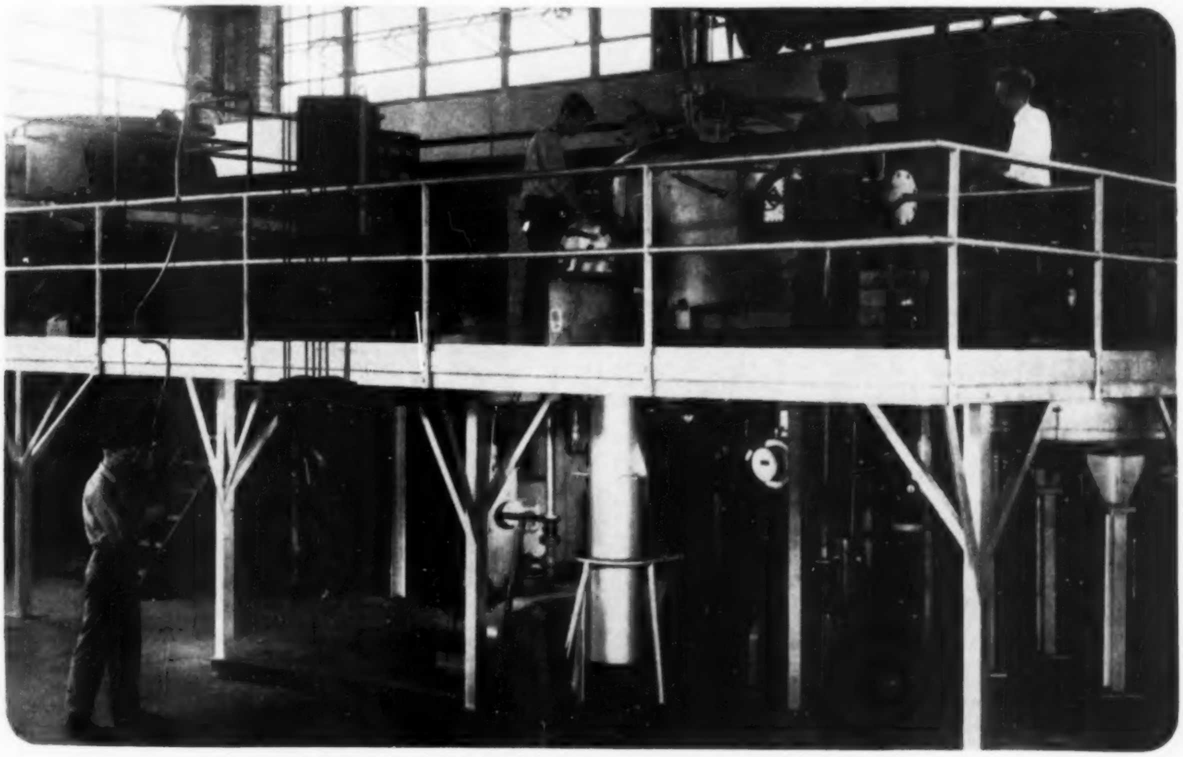

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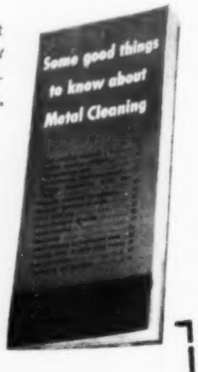

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